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(54) Title: METHODS OF PREPARING CANNABINOIDS FROM PLANT MATERIAL

(57) Abstract: The invention relates to methods of preparing cannabinoids in substantially pure form starting from plant material. Also described are substantially pure preparations of various cannabinoids and cannabinoid acids, and also extracts enriched in cannabinoids and cannabinoid acids.

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Methods of preparing cannabinoids from plant materialField of the invention

The invention relates to methods of preparing  
5 cannabinoids in substantially pure form starting from  
plant material.

Background to the invention

Cannabis has been used medicinally for many  
10 years, and in Victorian times was a widely used  
component of prescription medicines. It was used as a  
hypnotic sedative for the treatment of "hysteria,  
delirium, epilepsy, nervous insomnia, migraine, pain  
and dysmenorrhoea". Historically, cannabis was  
15 regarded by many physicians as unique; having the  
ability to counteract pain resistant to opioid  
analgesics, in conditions such as spinal cord injury,  
and other forms of neuropathic pain including pain and  
spasm in multiple sclerosis.

20 The use of cannabis continued until the middle of  
the twentieth century, when the recreational use of  
cannabis prompted legislation which resulted in the  
prohibition of its use. The utility of cannabis as a  
25 prescription medicine is now being re-evaluated. The  
discovery of specific cannabinoid receptors and new  
methods of administration have made it possible to  
extend the use of cannabis-based medicines to historic  
and novel indications.

30 The principle cannabinoid components present in  
herbal cannabis are the cannabinoid acids  $\Delta^9$   
tetrahydrocannabinolic acid ( $\Delta^9$  THCA) and  
cannabidiolic acid (CBDA), with small amounts of the  
35 corresponding neutral cannabinoids, respectively  $\Delta^9$   
tetrahydrocannabinol ( $\Delta^9$  THC) and cannabidiol (CBD).  
Cannabidiol was formerly regarded as an inactive  
constituent, however there is emerging evidence that  
it has pharmacological activity, which is different  
40 from that of  $\Delta^9$  THC in several respects.

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In addition to these major cannabinoids, herbal cannabis may contain lower levels of other minor cannabinoids. These may be intermediates in the biosynthesis of the major cannabinoids and hence exist at only low levels in the plant as they are constantly undergoing further biotransformation once they are formed. An example of such a cannabinoid is cannabigerol (CBG). Other minor cannabinoids may represent the end point of an alternative biosynthetic pathway to that leading to the formation of the major cannabinoids  $\Delta^9$  THC and CBD. These cannabinoids are frequently relatively more abundant in the plant, an example being cannabichromene (CBC).

A special example of a minor cannabinoid that is the end point of a biosynthetic pathway is  $\Delta^9$  Tetrahydrocannabivarin ( $\Delta^9$  THCV). This compound is closely related to  $\Delta^9$  THC, with the only difference in structure being the presence of a propyl ( $C_3H_7$ ) side chain rather than a pentyl ( $C_5H_{11}$ ) side chain on the aromatic ring. This compound usually accompanies  $\Delta^9$  THC at a level of 1-2% of THC present. However in certain selectively bred varieties of cannabis  $\Delta^9$  THCV can account for greater than 70% of total cannabinoids, with  $\Delta^9$  THC being reduced to the level of a minor constituent.

Purified forms of certain of the cannabinoids present in herbal cannabis are useful as active pharmaceutical agents. For example,  $\Delta^9$  THC (also known as dronabinol) has been approved by the Food and Drug Administration (FDA) for the control of nausea and vomiting associated with chemotherapy, and also shows potential pharmacological activity in the treatment of glaucoma, migraine headaches, anxiety, and as an analgesic. Cannabidiol, formerly regarded as an inactive constituent of cannabis, has, as aforesaid, itself shown promising pharmacological activity.

In the case of the minor cannabinoids, the difficulties in isolating the minor cannabinoids in a pure state and the absence of commercially available standards have restricted the investigation of the pharmacology of these compounds and their true therapeutic potential is unknown. Consequently it is of great interest to isolate sufficiently pure samples of these cannabinoids in the quantities required to permit pharmacological studies to be performed.

Purified forms of the cannabinoids and cannabinoid acids are also potentially useful as analytical standards, particularly in the characterisation of cannabis-derived medicines based on botanical drug substances prepared from herbal cannabis.

Thus, there remains a need for purified forms of all of the cannabinoid acids and cannabinoids present in cannabis herb, including the major cannabinoids  $\Delta^9$  THC and CBD and the minor cannabinoids.

Synthetic forms of certain of the cannabinoids, particularly  $\Delta^9$  THC, CBD and CBN, are commercially available. However, synthetic cannabinoids are extremely expensive. Attention has therefore focussed on the purification of cannabinoids from plant material.

WO 02/32420 discloses a process for preparing, for example,  $\Delta^9$ -THC from plant material. It utilises CO<sub>2</sub> extraction and ethanol precipitation to obtain "primary extracts" containing  $\Delta^9$ -THC and CBD, with reduced amounts of, for example, monoterpenes, sesquiterpenes, hydrocarbons, alkaloids, flavonoids and chlorophylls. The CBD is then converted to  $\Delta^9$ -THC by a catalysing reaction. The cannabinoids make up only approximately two-thirds of the composition and are therefore not substantially pure.

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US 6,403,126 discloses a process in which THC is removed from a cannabis extract using chromatography.

5 JP 3153625 discloses a method of producing an anti-allergic agent. In one example, dry seeds of cannabis are subjected to multiple extraction steps and multiple chromatographic steps.

10 Biochemical Medicine (1973, vol. 8, P.341-344) discloses a multi-step extraction and purification process for producing  $\Delta^9$ -THC of unspecified purity.

15 ODCCP Bulletin on Narcotics (1976, Issue 4) discloses a method of isolating CBD, THC and CBN using preparative gas chromatography.

20 US-A-6,365,416 describes a method of preparing  $\Delta^9$  THC from plant material which involves extracting the plant material with a non-polar organic solvent, optionally subjecting the extract to a column chromatography step to produce a residue eluate, subjecting the extract or the residue eluate to a low pressure flash distillation to produce a distillate, 25 optionally subjecting the distillate to a second flash distillation step, and subjecting the distillate to column chromatography, normal HPLC or reverse-phase HPLC. The process provides a product containing  $\Delta^9$  THC in an amount greater than 90% by weight.

30 There remains a need for alternative purification processes which may be used to prepare purified forms of all cannabinoid and cannabinoid acid constituents of cannabis herb, including the cannabinoid acids  $\Delta^9$  35 THCA and CBDA, the corresponding free cannabinoids  $\Delta^9$  THC and CBD, and the minor cannabinoids. The present invention relates to such a purification process based on a simple combination of solvent extraction, chromatography and re-crystallisation steps. The 40 process is simple, efficient and economic, and is

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capable of producing cannabinoids of high purity,  
whilst avoiding the need for preparatory HPLC.

#### Summary of the invention

5 In a first aspect the invention provides a method  
of obtaining a substantially pure cannabinoid or  
cannabinoid acid or a product enriched in a given  
cannabinoid or cannabinoid acid comprising:

10 i) obtaining an extract containing a cannabinoid or  
cannabinoid acid from a plant material;

ii) subjecting the extract of step (i) to a  
chromatographic step to produce a partially purified  
extract;

15 iii) dissolving the partially purified extract in a  
first solvent, removing any insoluble material  
therefrom, and removing the solvent; and

20 iv) dissolving the product obtained in step iii) in a  
second solvent, removing any insoluble material  
therefrom, and removing the solvent to obtain the  
substantially pure cannabinoid or cannabinoid acid or  
the product enriched in a given cannabinoid or  
cannabinoid acid, wherein the first and second  
solvents are different, and wherein one of the first  
or second solvents is a solvent which is substantially  
25 more polar than the cannabinoid/cannabinoid acid which  
it is desired to purify, and the other solvent is a  
solvent which is substantially less polar than the  
cannabinoid/cannabinoid acid which it is desired to  
purify.

30 The method may optionally comprise a further step  
v) of flash chromatography as an optional further  
purification step. In the most preferred embodiment  
the flash chromatography step may comprise the  
35 following:

v) loading the substantially pure cannabinoid or  
cannabinoid acid or the product enriched in a given  
cannabinoid or cannabinoid acid onto a Chromabond  
Flash BT 12M silica cartridge column, eluting with  
40 hexane:ethyl acetate (98:2) at a flow rate of  
approximately 5 ml/min.

The invention further relates to substantially pure preparations of various cannabinoids and cannabinoid acids and also products enriched in various cannabinoids and cannabinoid acids.

#### Description of the invention

The invention relates to a purification process for preparing substantially pure cannabinoid or cannabinoid acid or a product enriched in a given cannabinoid or cannabinoid acid from plant material.

A "substantially pure" preparation of cannabinoid or cannabinoid acid is defined as a preparation having a chromatographic purity (of the desired cannabinoid or cannabinoid acid) of greater than 95%, more preferably greater than 96%, more preferably greater than 97%, more preferably greater than 98%, more preferably greater than 99% and most preferably greater than 99.5%, as determined by area normalisation of an HPLC profile.

The term "product enriched in a given cannabinoid or cannabinoid acid" encompasses preparations having at least 80%, preferable greater than 85%, more preferably greater than 90% chromatographic purity for the desired cannabinoid or cannabinoid acid. Such a product will generally contain a greater proportion of impurities, non-target materials and other cannabinoids than a "substantially pure" preparation.

The method of the invention may be used to extract/purify cannabinoids or cannabinoid acids from any plant material known to contain such cannabinoids or cannabinoid acids. Most typically, but not necessarily, the "plant material" will be derived from one or more cannabis plants.

The term "plant material" encompasses a plant or plant part (e.g. bark, wood, leaves, stems, roots,

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flowers, fruits, seeds, berries or parts thereof) as well as exudates, and includes material falling within the definition of "botanical raw material" in the Guidance for Industry Botanical Drug Products Draft Guidance, August 2000, US Department of Health and Human Services, Food and Drug Administration Centre for Drug Evaluation and Research.

The term "cannabis plant(s)" encompasses wild type *Cannabis sativa* and also variants thereof, including cannabis chemovars (varieties characterised by virtue of chemical composition) which naturally contain different amounts of the individual cannabinoids, also *Cannabis sativa* subspecies *indica* including the variants *var. indica* and *var. kafiristanica*, *Cannabis indica* and also plants which are the result of genetic crosses, self-crosses or hybrids thereof. The term "cannabis plant material" is to be interpreted accordingly as encompassing plant material derived from one or more cannabis plants. For the avoidance of doubt it is hereby stated that "cannabis plant material" includes herbal cannabis and dried cannabis biomass.

"Decarboxylated cannabis plant material" refers to cannabis plant material which has been subject to a decarboxylation step in order to convert cannabinoid acids to the corresponding free cannabinoids.

The starting material for the purification process is an extract containing a cannabinoid or cannabinoid acid obtained from a plant material.

In a preferred embodiment the "extract containing a cannabinoid or cannabinoid acid" may be a solvent extract of a plant material. Preferred extraction solvents for use in the preparation of this extract include non-polar solvents, also alcohols such as ethanol or methanol and liquid carbon dioxide. Preferably the extract is prepared by dissolving



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plant material in an extraction solvent, removing insoluble material from the resultant solution (preferably by filtration), and removing the extraction solvent from the solution (preferably by rotary evaporation) to form an extract containing a cannabinoid or cannabinoid acid.

Non-polar solvents are particularly preferred for preparing an initial extract from the starting plant material. Any non-polar solvent capable of solubilising cannabinoids or cannabinoid acids may be used. Preferred non-polar solvents include liquid non-polar solvents comprising lower C5-C12, preferably C5 to C8, straight chain or branched chain alkanes. The most preferred non-polar solvent for the preparation of free cannabinoids is hexane.

In embodiments wherein the method is to be used for the isolation of cannabinoid acids then it is preferred to use an acidified extraction solvent to prepare the initial extract. The primary purpose of this acidification is to prevent/minimise ionisation of the cannabinoid acid, which could otherwise adversely affect the purification process. It is preferred to use acidified non-polar solvents, of the types described above. Acidification may be achieved by the additional of a small volume of acid to the solvent. Generally it is sufficient to add a relatively weak acid, such as acetic acid. For any given purification process the optimal amount and type of acid used may be determined empirically. A preferred acidified solvent is 0.1% acetic acid in hexane. This is the extraction solvent of choice for preparing an initial extract from the starting plant material in the preparation of cannabinoid acids.

In embodiments of the method where it is desired to purify free cannabinoids, rather than the cannabinoid acids, the plant material may be subjected to a decarboxylation step prior to step (i). The

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purpose of the decarboxylation step is to convert cannabinoid acids present in the plant material to the corresponding free cannabinoids. Decarboxylation is preferably carried out by heating the plant material to a defined temperature for a suitable length of time. Decarboxylation of cannabinoid acids is a function of time and temperature, thus at higher temperatures a shorter period of time will be taken for complete decarboxylation of a given amount of cannabinoid acid. In selecting appropriate conditions for decarboxylation consideration must, however, be given to minimising thermal degradation of the desirable, pharmacological cannabinoids into undesirable degradation products, particularly thermal degradation of  $\Delta^9$  THC to cannabinol (CBN).

Preferably, decarboxylation is carried out in a multi-step heating process in which the plant material is:

- i) heated to a first temperature for a first (relatively short) time period to evaporate off retained water and allow for uniform heating of the plant material; and
- ii) the temperature is increased to a second temperature for a second time period (typically longer than the first time period) until at least 95% conversion of the acid cannabinoids to their neutral form has occurred.

Preferably the first step is conducted at a temperature in the range of from 100°C to 110°C for 10-20min. More preferably the first temperature is about 105°C and the first time period is about 15 minutes.

Optimum times and temperatures for the second step may vary depending on the nature of the plant material, and more particularly on the cannabinoid which it is intended to isolate from the plant.

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material, and may be easily determined by routine experiment. Suitable conditions may include, for example, a temperature in the range of from 115°C to 125°C for a time period in the range of from 45 to 75 minutes (typically 120°C for 60 minutes), or a temperature in the range of from 135°C to 145°C, for a time period in the range of from 15 to 45 minutes.

If the plant material is derived from cannabis plants having a high THC content (defined as >90% THC as a percentage of total cannabinoid content), the second temperature is preferably in the range of from 115°C to 125°C, typically 120°C, and the second time period is preferably in the range of from 45 minutes to 75 minutes, typically about 60 minutes. More preferably the second temperature is in the range of from 100°C to 110°C, typically 105°C, and the second time period is in the range of from 60 to 120 minutes. In another embodiment, most preferred for a mass of plant material greater than 4kg, the second temperature is in the range of from 140°C to 150°C, preferably 145°C, and the second time period is in the range of from 45 to 55 minutes.

Where the starting "plant material" is freshly harvested or "wet" plant material is may be subjected to a drying step to remove excess moisture prior to step (i). For convenience, decarboxylation and drying may be combined in a single heating step or in a multi-step heating process, as described above.

In a particular embodiment of the method of the invention the "extract containing a cannabinoid or cannabinoid acid" prepared from the starting plant material may be a "botanical drug substance" prepared from the plant material, or an ethanolic solution of such a botanical drug substance. In the context of this application a "botanical drug substance" is an extract derived from plant material, which extract fulfils the definition of "botanical drug substance"

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provided in the Guidance for Industry Botanical Drug Products Draft Guidance, August 2000, US Department of Health and Human Services, Food and Drug Administration Centre for Drug Evaluation and Research.

5 of: "A drug substance derived from one or more plants, algae, or macroscopic fungi. It is prepared from botanical raw materials by one or more of the following processes: pulverisation, decoction, expression, aqueous extraction, ethanolic extraction,

10 or other similar processes."

"Botanical drug substances" derived from cannabis plants include primary extracts prepared by such processes as, for example, maceration, percolation,

15 and solvent extraction. Solvent extraction may be carried out using essentially any solvent that dissolves cannabinoids/cannabinoid acids, such as for example C1 to C5 alcohols (e.g. ethanol, methanol), C5-C12 alkanes (e.g. hexane), Norflurane (HFA134a),

20 HFA227 and carbon dioxide. When solvents such as those listed above are used, the resultant extract typically contains non-specific lipid-soluble material. This can be removed by a variety of processes including "winterisation", which involves

25 chilling to -20°C followed by filtration to remove waxy ballast, extraction with liquid carbon dioxide and by distillation. General protocols for the preparation of botanical drug substances from cannabis plant material are described in the applicant's

30 published International patent application WO 02/064109.

The botanical drug substance is preferably obtained by carbon dioxide (CO<sub>2</sub>) extraction followed

35 by a secondary extraction, e.g. an ethanolic precipitation, to remove a substantial proportion of non-cannabinoid materials, e.g. waxes, wax esters and glycerides, unsaturated fatty acid residues, terpenes, carotenes, and flavenoids and other ballast. Most

40 preferably the botanical drug substance is produced by

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a process comprising extraction with liquid CO<sub>2</sub>, under sub-critical or super-critical conditions, and then a further extraction, preferably an ethanolic precipitation, to remove significant amounts of ballast.

If it is intended to prepare free cannabinoids from the cannabis plant material then the material is preferably heated to a defined temperature for a defined period of time in order to decarboxylate cannabinoid acids to free cannabinoids prior to extraction of the botanical drug substance.

In the most preferred embodiment the botanical drug substance is prepared according to a process comprising the following steps:

- i) optional decarboxylation of the plant material,
- ii) extraction with liquid CO<sub>2</sub> (most preferably under sub-critical conditions), to produce a crude botanical drug substance,
- iii) precipitation with C1-C5 alcohol to reduce the proportion of non-target materials,
- iv) removal of the precipitate (preferably by filtration),
- v) optional treatment with activated charcoal, and
- vi) evaporation to remove C1-C5 alcohol and water, thereby producing a final botanical drug substance.

A detailed example of such a process is described in the accompanying Examples.

The "extract containing a cannabinoid or cannabinoid acid" is subjected to a chromatographic purification step to produce a partially purified extract. The purpose of this step is to reduce the amount of "non-target", i.e. non-cannabinoid or non-cannabinoid acid material, in the extract and also to provide a degree of separation/fractionation of the various cannabinoid/cannabinoid acid components of the crude plant extract obtained in step (i). Typically,

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the product of the chromatographic step is collected in multiple fractions, which may then be tested for the presence of the desired cannabinoid/cannabinoid acid using any suitable analytical technique (e.g. TLC). Fractions enriched in the desired cannabinoid/cannabinoid acid may then be selected for further purification.

The chromatographic step will preferably comprise column chromatography, and is preferably based on molecular sizing and polarity. Preferred column matrix materials are hydrophilic lipophilic materials, for example hydroxypropylated cross-linked dextrans such as Sephadex LH-20™. Various different solvents may be used in combination with this type of matrix, for example dimethyl sulphoxide, pyridine, water, dimethylformamide, methanol, saline, ethylene dichloride, chloroform, propanol, ethanol, isobutanol, formamide, methylene dichloride, butanol, isopropanol, tetrahydrofuran, dioxane, chloroform/dichloromethane etc.

In the most preferred embodiment the chromatographic step comprises column chromatography on a Sephadex LH-20™ column, preferably eluting with a 2:1 mixture of chloroform/dichloromethane. However, any suitable combination of column packing material and solvent having separation characteristics suitable for use in separation (fractionation) of cannabinoids and cannabinoid acids may be used with equivalent effect. The column eluate is typically collected in several fractions. The fractions are tested for the presence of the desired cannabinoid/cannabinoid acid using a suitable analytical technique, and those fractions containing the highest amounts of the desired cannabinoid or cannabinoid acid selected for further processing. Solvent is then removed from the selected fractions, preferably by rotary evaporation.

The partially purified product obtained from the

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chromatographic step is re-dissolved in a first solvent. Any insoluble residues (e.g. particulate material) are removed from the resultant solution, typically by filtration. The first solvent is then removed, preferably by rotary evaporation. The product of this step is re-dissolved in a second solvent. Again, any insoluble residues (e.g. particulate material) are removed from the resultant solution, typically by filtration. The second solvent is then removed, preferably by rotary evaporation, to produce the final product, which is a substantial pure cannabinoid or cannabinoid acid or a product enriched in a given cannabinoid or cannabinoid acid.

The purpose of these two "solvent treatment" steps is to remove contaminants, leaving a substantially pure preparation of the desired cannabinoid or cannabinoid acid.

In the preferred embodiment the first and second solvents are different. One of the first or second solvents is a solvent which is substantially more polar than the cannabinoid/cannabinoid acid which it is desired to purify. Treatment with this solvent has the effect of removing unwanted components that are less polar than the desired cannabinoid/cannabinoid acid. The other solvent is a solvent which is substantially less polar than the cannabinoid/cannabinoid acid which it is desired to purify. Treatment with this solvent has the effect of removing unwanted components that are more polar than the desired cannabinoid/cannabinoid acid. The combined effect of sequential treatment with two such solvents is of "topping and tailing" the partially purified extract to yield a substantially pure product. The two solvent treatment steps may be performed in either order. It is immaterial to the overall purification whether the "less polar" or "more polar" contaminants are removed first.

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The first and second solvents may be essentially any solvents that dissolve cannabinoids and/or cannabinoid acids and which have the desired polarity in comparison to the cannabinoid/cannabinoid acid which it is desired to isolate.

Preferred solvents for use in these treatment steps include alcohols, particularly C1-C5 alcohols, with methanol being particularly preferred, and also C5-C12 straight or branched chain alkanes, most preferably pentane. A particularly preferred combination of first and second solvents, which is suitable for use in the preparation of the majority of cannabinoids and cannabinoid acids, is methanol and pentane. These solvents may be used in either order.

The process of the invention generally results in the isolation of substantially pure cannabinoids or cannabinoid acids of high chromatographic purity. Substantially pure cannabinoids or cannabinoid acids are often obtained as crystalline solids or clear colourless solutions. The inventors have determined that the process of the invention may be used to prepare substantially pure preparations of cannabinoids or cannabinoid acids having a higher degree of chromatographic purity than the preparations previously known in the prior art. Therefore, in an extremely important aspect, the process of the invention provides a solution to the problem of preparing/isolating cannabinoids and cannabinoid acids at a high degree of purity. The process is advantageously cheap, amenable to scale-up and applicable to a wide range of different cannabinoids and cannabinoid acids.

The process of the invention may be used to prepare substantially pure forms, or products enriched in, essentially any cannabinoids or cannabinoid acids which occur naturally in plant material (including free cannabinoid forms of naturally occurring



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cannabinoid acids).

The essential features of the process are the same for purification of all cannabinoids and  
5 cannabinoids acids. Cannabis plants generally contain complex mixtures of cannabinoid acids and cannabinoids, although depending on the variety of cannabis one type of cannabinoid may pre-dominate. The purpose of the chromatographic step (ii) is to  
10 separate the various cannabinoid/cannabinoid acid components of the crude plant extract obtained in step (i). Typically, the product of the chromatographic step is collected in multiple fractions, which may then be tested for the presence of the desired  
15 cannabinoid/cannabinoid acid using any suitable analytical technique (e.g. TLC). Fractions enriched in the desired cannabinoid/cannabinoid acid may then be selected for further purification. Hence, the same simple process steps may be adapted for purification  
20 of essentially any plant-derived cannabinoid or cannabinoid acid.

Selectivity for different cannabinoids or cannabinoid acids may be enhanced by selection of  
25 appropriate starting plant material. By way of example, if it is desired to prepare substantially pure  $\Delta^9$  THC or  $\Delta^9$  THCA then "high THC" cannabis plants should preferably be selected as the starting material. Whereas, if it is desired to prepare  
30 substantially pure CBD or CBDA then "high CBD" cannabis plants should preferably be selected as the starting material. However, it is to be understood that the process of the invention is of general utility and is not limited to the use of particular  
35 cannabis varieties as the starting material.

Working with Cannabis plants and cannabinoids may require a Government licence in some territories but Governments generally make such licences available to  
40 parties who apply for the purposes of medicinal

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research and commercial development of medicines. In the United Kingdom a licence may be obtained from the Home Office.

5           The precise cannabinoid content of any particular cannabis plant material may be qualitatively and quantitatively determined using analytical techniques well known to those skilled in the art, such as thin-layer chromatography (TLC) or high performance liquid  
10       chromatography (HPLC). Thus, one may screen a range of from cannabis plants and select those having a high content of the desired cannabinoid acid or cannabinoid for use as starting material in the process of the invention.

15           With the use of conventional selective breeding techniques it is possible to develop cannabis varieties (chemovars) having varying cannabinoid content. Using such traditional selective breeding  
20       techniques the inventors have been able to select cannabis varieties (chemovars) having relatively high content of CBD, or of the minor cannabinoids  $\Delta^9$  tetrahydrocannabivarin ( $\Delta^9$  THCV), cannabigerol (CBG) or cannabichromene (CBC). General protocols for  
25       growing of medicinal cannabis and for testing the cannabinoid content of cannabis plants are described in the applicant's published International patent application WO 02/064109.

30           Where it is desired to purify free cannabinoids, rather than the corresponding cannabinoid acids, then the process will generally include a "decarboxylation" step to decarboxylate free cannabinoid acids to the corresponding free cannabinoid. As aforesaid, a  
35       decarboxylation step may be included prior to step (i) if it is desired to isolate free cannabinoids, or omitted if it is desired to isolate cannabinoid acids.

40           The process of the invention is particularly preferred for use in the preparation of substantially

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pure  $\Delta^9$  tetrahydrocannabinolic acid ( $\Delta^9$  THCA),  
cannabidiolic acid (CBDA),  $\Delta^9$  tetrahydrocannabinol ( $\Delta^9$   
THC) and  $\Delta^9$  tetrahydrocannabivarin ( $\Delta^9$  THCV) from  
cannabis plant material, and in the preparation of  
5 extracts of cannabis plant material highly enriched in  
cannabigerol (CBG) or cannabichromene (CBC).

The invention further relates to substantially  
pure preparations of certain cannabinoids and  
10 cannabinoids and to products highly enriched in  
certain cannabinoids.

In particular, the invention provides a  
substantially pure preparation of  $\Delta^9$   
15 tetrahydrocannabinolic acid ( $\Delta^9$  THCA) having a  
chromatographic purity of greater than 95%, more  
preferably greater than 96%, more preferably greater  
than 97% and most preferably greater than 98% by area  
normalisation of an HPLC profile. The preparation is  
20 typically a pale yellow crystalline solid at room  
temperature, having a melting point of  $\sim 70^\circ\text{C}$ .

The preparation preferably comprises:  
less than 2%, preferably less than 1.5%, most  
25 preferably 1% or less  $\Delta^9$  THC (w/w),

less than 2%, more preferably less than 1.5%, more  
preferably less than 1% and most preferably less than  
0.5% CBD (w/w),

30 less than 2%, more preferably less than 1.5%, and most  
preferably less than 1% CBN (w/w).

The inventors are the first to isolate  $\Delta^9$  THCA  
35 from plant material at this level of purity in  
crystalline form. Pure  $\Delta^9$  THCA is useful as a  
starting material for the preparation of pure  $\Delta^9$  THC  
by decarboxylation, also as a chromatographic  
standard.

40

- 19 -

The preferred method for preparation of substantially pure  $\Delta^9$  THCA from cannabis plant material comprises:

- 5 i) preparing an extract of the cannabis plant material with 0.1% v/v acetic acid in hexane,
- ii) filtering the resultant extract and removing solvent from filtrate by rotary evaporation to form an extract enriched in  $\Delta^9$  THCA,
- 10 iii) passing a solution of the resulting  $\Delta^9$  THCA enriched extract through a column packed with Sephadex-LH20™, eluting with 2:1 chloroform/dichloromethane,
- iv) collecting  $\Delta^9$  THCA rich fractions eluted from the
- 15 column and removing solvent by rotary evaporation,
- v) re-dissolving the crude  $\Delta^9$  THCA obtained in step iv) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,
- 20 vi) re-dissolving the product of step v) in pentane, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation to produce  $\Delta^9$  THCA crystals.

25 The cannabis plant material will preferably be derived from cannabis plants having a relatively high  $\Delta^9$  THCA content, most preferably cannabis plants containing >90%  $\Delta^9$  THCA as a percentage of total cannabinoid content.

30 The invention further provides a substantially pure preparation of cannabidiolic acid (CBDA) having a chromatographic purity of greater than 90%, more preferable greater than 92% and most preferably greater than 94% by area normalisation of an HPLC

35 profile. The preparation is typically a pale yellow crystalline solid at room temperature, having a melting point in the range of from 45-48°C.

40 The preparation preferably comprises:  
5% or less, preferably 4.5% or less, more preferably

- 20 -

4% or less, more preferably 3.5% or less and most preferably 3% or less CBD (w/w),

5 less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% and most preferably less than 0.1%  $\Delta^9$  THCA (w/w),

10 less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% and most preferably less than 0.1%  $\Delta^9$  THC (w/w).

15 Again, the inventors are the first to isolate CBDA from plant material at this level of purity in crystalline form.

20 The invention further provides a substantially pure preparation of cannabidiolic acid (CBDA) having a chromatographic purity of greater than 94%, more preferably greater than 96% and most preferably greater than 98% by area normalisation of an HPLC profile. The preparation is preferably a clear colourless solution at room temperature.

25 The preparation typically comprises:  
3%-or less, more preferably 2% or less, more preferably 1% or less and most preferably 1% or less and most preferably less than 0.1% CBD (w/w),

30 less than 0.8%, more preferably less than 0.6%, more preferably less than 0.3% THCA (w/w),

35 less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% and most preferably less than 0.1%  $\Delta^9$ -THC (w/w).

40 Pure CBDA is useful as a starting material for the preparation of pure CBD by decarboxylation, also

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as a chromatographic standard and may also have pharmaceutical potential. The ability to prepare CBDA at a high level of purity will permit further studies of the pharmaceutical utility of this cannabinoid acid.

The preferred method for preparation of substantially pure CBDA from cannabis plant material comprises:

10

- i) preparing an extract of the cannabis plant material with 0.1% v/v acetic acid in hexane,
- ii) filtering the resultant extract and removing solvent from filtrate by rotary evaporation to form an extract enriched in CBDA,
- 15 iii) passing a solution of the resulting CBDA enriched extract through a column packed with Sephadex-LH20™, eluting with 2:1 chloroform/dichloromethane,
- iv) collecting CBDA rich fractions eluted from the column and removing solvent by rotary evaporation,
- 20 v) re-dissolving the crude CBDA obtained in step iv) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,
- 25 vi) re-dissolving the product of step v) in pentane, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation to produce CBDA crystals or a solution.

30

The cannabis plant material will preferably be derived from cannabis plants having a relatively high CBDA content, most preferably cannabis plants containing >90% CBDA as a percentage of total cannabinoid content.

35

Where the product of the method is a CBDA solution, the method may optionally include a further purification step of flash chromatography, comprising The method may optionally include a further purification step of flash chromatography comprising

40 vii) loading the substantially pure solution of CBDA

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onto a Chromabond Flash BT 12M silica cartridge column, eluting with hexane:ethyl acetate (98:2) at a flow rate of approximately 5 ml/min..

5       The invention further provides a substantially pure preparation of  $\Delta^9$  tetrahydrocannabinol ( $\Delta^9$  THC) having a chromatographic purity of greater than 99% by area normalisation of an HPLC profile. The preparation is a semi-solid at room temperature.

10

The preparation preferably comprises less 0.5%, preferably than 0.4%, more preferably less than 0.2% and most preferably less than 0.1% CBD (w/w),

15

less than 0.5%, preferably less than 0.4%, more preferably less than 0.2% and most preferably less than 0.1% CBN (w/w).

20

Most preferably the preparation contains no detectable (<0.1%) CBD and no detectable CBN (<0.1%), as analysed by HPLC.

25

The inventors are the first to isolate  $\Delta^9$  THC from plant material at >99% purity and in semi-solid form.  $\Delta^9$  THC has previously been reported in the literature as a yellow oil and has never been obtained in crystalline form. The pure  $\Delta^9$  THC is of obvious utility as an active pharmaceutical agent, and is also useful as a chromatographic standard, particularly as

30 a comparative standard in the qualitative analysis of botanical drug substances derived from cannabis. The availability of highly pure  $\Delta^9$  THC will also facilitate studies of the pharmacology of  $\Delta^9$  THC.

35

The preferred method for preparation of substantially pure  $\Delta^9$  THC comprises:

40

- i) obtaining an ethanolic solution of a botanical drug substance from decarboxylated cannabis plant material,
- ii) passing the solution obtained in step i) through a

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column of activated charcoal, and collecting the eluate,

iii) remove solvent from the eluate by rotary evaporation to give a  $\Delta^9$  THC enriched fraction,

5 iv) passing a solution of the resulting  $\Delta^9$  THC enriched extract through a column packed with Sephadex LH20, eluting with 2:1 chloroform/dichloromethane,

v) collecting  $\Delta^9$  THC rich fractions and removing solvent by rotary evaporation,

10 vi) re-dissolving the crude  $\Delta^9$  THC prepared in step v) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,

vii) re-dissolving the crude  $\Delta^9$  THC prepared in step

15 vi) in pentane, removing insoluble residue by filtration and removing solvent from the filtrate by rotary evaporation to give a semi-solid preparation of  $\Delta^9$  THC.

20 In this method the ethanolic solution of a botanical drug substance from decarboxylated cannabis plant material is preferably obtained by a method comprising the following steps:

25 i) harvesting cannabis plant material,

ii) decarboxylation of the plant material,

iii) extraction with liquid carbon dioxide ( $\text{CO}_2$ ), removal of  $\text{CO}_2$  to recover crude extract,

30 iv) dissolution of crude extract in ethanol followed by chilling of the solution to precipitate unwanted waxes,

v) removal of unwanted waxy material by cold filtration.

35 The (decarboxylated) cannabis plant material will preferably be derived from cannabis plants having a relatively high THC content, most preferably cannabis plants containing >90% THC ( $\Delta^9$  THCA plus  $\Delta^9$  THC) as a percentage of total cannabinoid content. The plant  
40 material is subject to decarboxylation in order to



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convert the naturally occurring  $\Delta^9$  THCA into  $\Delta^9$  THC.

The invention still further relates to a substantially pure preparation of  $\Delta^9$  tetrahydrocannabivarin ( $\Delta^9$  THCV) having a chromatographic purity of greater than 95%, more preferable greater than 96%, more preferable greater than 97%, more preferable greater than 98%, and most preferable greater than 99% by area normalisation of an HPLC profile. The preparation is typically a crystalline solid at room temperature.

The preparation preferably comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% and most preferably less than 0.1% CBD (w/w),

less than 2.0%, preferably less than 1.5%, more preferably less than 1.0% and most preferably 0.5% or less  $\Delta^9$  THC (w/w),

less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% and most preferably less than 0.1% CBN (w/w).

Again the inventors are the first to isolate  $\Delta^9$  THCV from plant material at this level of purity and in crystalline form. The availability of pure  $\Delta^9$  THCV will permit studies of the pharmacology of this minor cannabinoid and evaluation of its pharmaceutical potential. Pure  $\Delta^9$  THCV is also useful as a chromatographic standard and as a starting material for the preparation of pure cannabivarin (CBV), for example by thermal degradation of  $\Delta^9$  THCV in air.

The preferred method for preparation of substantially pure  $\Delta^9$  THCV from plant material comprises:

- 25 -

- i) obtaining an ethanolic solution of a botanical drug substance from cannabis plant material,
- ii) passing the solution obtained in step i) through a column of activated charcoal, and collecting the eluate,
- iii) remove solvent from the eluate by rotary evaporation to give a  $\Delta^9$  THCv enriched fraction,
- iv) passing a solution of the resulting  $\Delta^9$  THCv enriched extract through a column packed with Sephadex LH20, eluting with 2:1 chloroform/dichloromethane,
- v) collecting  $\Delta^9$  THCv rich fractions and removing solvent by rotary evaporation,
- vi) re-dissolving the crude  $\Delta^9$  THCv prepared in step v) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,
- vii) re-dissolving the crude  $\Delta^9$  THCv prepared in step vi) in pentane, removing insoluble residue by filtration and removing solvent from the filtrate by rotary evaporation to give crystals of  $\Delta^9$  THCv.

The ethanolic solution of a botanical drug substance from cannabis plant material is preferably obtained by a method comprising the following steps:

- i) harvesting and decarboxylating cannabis plant material,
- ii) extraction with liquid carbon dioxide ( $\text{CO}_2$ ), removal of  $\text{CO}_2$  to recover crude extract,
- iii) dissolution of crude extract in ethanol followed by chilling of the solution to precipitate unwanted waxes,
- iv) removal of unwanted waxy material by cold filtration.

The cannabis plant material will preferably be derived from cannabis plants having a relatively high  $\Delta^9$  THCv content.

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The invention still further comprises a product enriched in cannabigerol (CBG) having a chromatographic purity of greater than 90%, preferably greater than 92% by area normalisation of an HPLC profile.

The product preferably comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% and most preferably less than 0.1% CBD (w/w),

less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% and most preferably 0.1% or less  $\Delta^9$  THC (w/w).

The product most preferably contains no detectable (<0.1%) CBN or CBD and no more than 0.1%  $\Delta^9$  THC, as analysed by HPLC.

Again, the inventors are the first to prepare cannabis plant extracts containing the minor cannabinoid CBG at this level of chromatographic purity.

The invention further provides a substantially pure preparation of cannabigerol (CBG) having a chromatographic purity of greater than 92%, more preferably greater than 94%, more preferably greater than 96% and most preferably greater than 97% by area normalisation of an HPLC profile. The preparation is preferably a clear colourless solution at room temperature.

The preparation typically comprises: 4% or less, more preferably 3% or less, and most preferably less than 2% CBD (w/w),

less than 1%, preferably less than 0.8%, more

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preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% and most preferably less than 0.1%  $\Delta^9$ -THC (w/w),

5 less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2%, and most preferably less than 0.1% CBN (w/w).

10 The availability of such enriched extracts or substantially pure preparations will permit further evaluation of the pharmacology of CBG in order to assess its pharmaceutical potential. The enriched extract/substantially pure preparation is also useful  
15 as a reference standard in chromatographic characterisation of cannabis-derived medicines.

The preferred method of preparing enriched CBG extracts or substantially pure preparations of CBG  
20 from cannabis plant material comprises:  
i) decarboxylating the cannabis plant material,  
ii) preparing an extract of the decarboxylated cannabis plant material with hexane,  
iii) filtering the resultant extract and removing  
25 solvent from filtrate by rotary evaporation to form an extract enriched in CBG,  
iv) passing a solution of the resulting CBG enriched extract through a column packed with Sephadex-LH20™, eluting with 2:1 chloroform/dichloromethane,  
30 v) collecting CBG rich fractions eluted from the column and removing solvent by rotary evaporation,  
vi) re-dissolving the crude CBG obtained in step v) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by  
35 rotary evaporation,  
vii) re-dissolving the product of step vi) in pentane, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation to produce a highly enriched CBG extract or substantially pure  
40 preparation of CBG.

The cannabis plant material will preferably be derived from cannabis plants having a relatively high CBG content.

5

Optionally a further step of flash chromatography may be conducted to further improve purity, preferably as set out in step viii) below. Such a step results in a further improvement in purity to greater than 99% (w/w). The skilled person will appreciate that an equivalent step could be used to improve purity for any of the other cannabinoids.

Step viii) loading the substantially pure cannabigerol or the cannabigerol enriched product onto a Chromabond Flash BT 12M silica cartridge column, eluting with hexam:ethyl acetate (98:2) at a flow rate of approximately 5ml/min.

10

15

20

The invention still further comprises a product enriched in cannabichromene (CBC) having a chromatographic purity of greater than 80%, more preferably greater than 85% by area normalisation of an HPLC profile.

25

The product preferably comprises less than 5%, preferably less than 4%, more preferably less than 3%, more preferably less than 2% and most preferably 1% or less CBD (w/w),

30

less than 2%, preferably less than 1.5%, more preferably less than 1.0%, more preferably less than 0.5% and most preferably 0.3% or less  $\Delta^9$  THC (w/w),

35

less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% and most preferably 0.1% or less CBN (w/w).

40

Again, the inventors are the first to prepare cannabis plant extracts containing the minor

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cannabinoid CBC at this level of chromatographic purity.

5 The invention further provides a substantially pure preparation of cannabichromene (CBC) having a chromatographic purity of greater than 85%, more preferably greater than 90%, more preferably greater than 95%, more preferably greater than 98% and most preferably greater than 99% by area normalisation of  
10 an HPLC profile. The preparation is a clear colourless solution at room temperature.

The preparation typically comprises:  
1% or less, more preferably 0.8% or less, more  
15 preferably 0.6% or less, more preferably 0.4% or less and most preferably less than 0.2% CBD (w/w),

less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than  
20 0.4%, more preferably less than 0.2% and most preferably less than 0.1%  $\Delta^9$ -THC (w/w),

less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than  
25 0.4%, more preferably less than 0.2% and most preferably less than 0.1% CBN (w/w).

The availability of such enriched  
30 extracts/substantially pure preparations will permit further evaluation of the pharmacology of CBC in order to assess its pharmaceutical potential. The enriched extract/substantially pure preparation is also useful as a reference standard in chromatographic characterisation of cannabis-derived medicines.

35

The preferred method for preparing enriched CBC extracts or substantially pure preparations of CBC from cannabis plant material comprises:

- 40 i) decarboxylating the cannabis plant material,
- ii) preparing an extract of the decarboxylated

- 30 -

cannabis plant material with hexane,

iii) filtering the resultant extract and removing solvent from filtrate by rotary evaporation to form an extract enriched in CBC,

5 iv) passing a solution of the resulting CBC enriched extract through a column packed with Sephadex-LH20™, eluting with 2:1 chloroform/dichloromethane,

v) collecting CBC rich fractions eluted from the column and removing solvent by rotary evaporation,

10 vi) re-dissolving the crude CBC obtained in step

v) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,

15 vii) re-dissolving the product of step vi) in pentane, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation to produce a highly enriched CBC extract or substantially pure preparation.

20 The cannabis plant material will preferably be derived from cannabis plants having a relatively high CBC content.

The method may optionally include a further  
25 purification step of flash chromatography comprising viii) loading the substantially pure preparation of CBC or the product enriched in CBC onto a Chromabond Flash BT 12M silica cartridge column, eluting with hexane:ethyl acetate (98:2) at a flow rate of  
30 approximately 5 ml/min.

The invention will be further understood with reference to the following experimental examples, together with the accompanying Figures, in which:

35

Figure 1 shows TLC a profile of crystalline  $\Delta^9$  THCA, compared to starting material (from G1 cannabis chemovar) and CBD and  $\Delta^9$  THC standards.

40 Chromatographic conditions: SII G/UV<sub>254</sub>, Mobile phase hexane:diethyl ether 80:20, double development, Visualisation 0.1% Fast Blue B salt in water.

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Standards: 1 mg/ml CBD (BN 10601/C) in MeOH 5 $\mu$ l applied to TLC plate, 1 mg/ml  $\Delta^9$  THC (BN 10601/B) in MeOH 5 $\mu$ l applied to TLC plate. Samples: 1 mg/ml THCA starting material in MeOH 5 $\mu$ l applied to TLC plate, 1 mg/ml crystalline THCA in MeOH 5 $\mu$ l applied to TLC plate.

Figure 2 shows HPLC profiles of purified  $\Delta^9$  THCA (98% THCA, 1% THC), compared to starting material (from G1 cannabis chemovar; 72% THCA, 17% THC).

Figure 3 shows TLC profile of crystalline CBDA, compared to starting material (from G5 cannabis chemovar) and CBD and  $\Delta^9$  THC standards.

Chromatographic conditions and standards as for Figure 1. Samples: 1 mg/ml CBDA starting material in MeOH 5 $\mu$ l applied to TLC plate, 1 mg/ml crystalline CBDA in MeOH 5 $\mu$ l applied to TLC plate.

Figure 4 shows HPLC profiles of crystalline CBDA (94% CBDA, 3% CBD), compared to starting material (from G5 cannabis chemovar; 72% CBDA, 14% CBD).

Figure 5 shows an HPLC profile of a colourless solution of CBDA (from G5 cannabis chemovar).

Figure 6 shows TLC profiles of purified  $\Delta^9$  THC compared to BDS starting material and CBD and  $\Delta^9$  THC standards. Chromatographic conditions and standards as for Figure 1. Samples: 1 mg/ml  $\Delta^9$  THC starting material in MeOH 5 $\mu$ l applied to TLC plate, 1 mg/ml purified  $\Delta^9$  THC in MeOH 5 $\mu$ l applied to TLC plate.

Figure 7 shows HPLC profiles of purified  $\Delta^9$  THC (99.6% THC, 0% CBD) compared to starting material (BDS; 89% THC, 2% CBD).

Figure 8 shows comparative HPLC profiles of purified  $\Delta^9$  THC and commercially available  $\Delta^9$  THC standard (Sigma; 95% THC, 4% CBN).



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Figure 9 shows GC profiles of purified  $\Delta^9$  THC and starting material (BDS).

5 Figure 10 shows TLC profiles of purified  $\Delta^9$  THCV and THCV starting material (BDS) compared to CBD and  $\Delta^9$  THC standards. Chromatographic conditions and standards as for Figure 1. Samples: 1 mg/ml  $\Delta^9$  THCV starting material in MeOH 5 $\mu$ l applied to TLC plate, 1  
10 mg/ml crystalline  $\Delta^9$  THCV in MeOH 5 $\mu$ l applied to TLC plate.

Figure 11 shows HPLC profiles of  $\Delta^9$  THCV and starting material (BDS).

15

Figure 12 shows GC profiles of purified  $\Delta^9$  THCV and starting material (BDS).

Figure 13 shows TLC profiles of enriched CBG extract and starting material (BDS from G41 chemovar-decarboxylated) compared to CBD and  $\Delta^9$  THC standards. Chromatographic conditions and standards as for Figure 1. Samples: 1 mg/ml CBG starting material in MeOH 5 $\mu$ l applied to TLC plate, 1 mg/ml enriched CBG extract in  
20 MeOH 5 $\mu$ l applied to TLC plate.  
25

Figure 14 shows HPLC profiles of enriched CBG extract and starting material (BDS from G41 chemovar-decarboxylated).

30

Figure 15 shows an HPLC profile of a colourless solution CBG preparation (from decarboxylated G41 cannabis chemovars).

35 Figure 16 shows an HPLC profile of further flash chromatography purified CBG preparation compared to improved purity CBG (from decarboxylated G41 cannabis chemovars).

40 Figure 17 shows GC profiles of enriched CBG extract

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and starting material (BDS from G41 chemovar-decarboxylated).

Figure 18 shows TLC profiles of enriched CBC extract and starting material (BDS from G80 chemovar-decarboxylated) compared to CBD and  $\Delta^9$  THC standards. Chromatographic conditions and standards as for Figure 1. Samples: 1 mg/ml CBC starting material in MeOH 5 $\mu$ l applied to TLC plate, 1 mg/ml purified enriched CBC extract in MeOH 5 $\mu$ l applied to TLC plate.

Figure 19 shows HPLC profiles of enriched CBC extract and starting material (BDS from G80 chemovar-decarboxylated).

Figure 20 shows an HPLC profile of a colourless solution CBC preparation (from decarboxylated G80 cannabis chemovars).

Figure 21 shows GC profiles of enriched CBC extract and starting material (BDS from G80 chemovar-decarboxylated).

## Examples

### Materials and methods

#### Plant material

GW Pharma Ltd has developed distinct varieties of Cannabis plant hybrids to maximise the output of the specific chemical constituents, cannabinoids. Various types of plant are used; one chemovar, designated G1 or "high THC" chemovar, produces >90% total cannabinoid content as  $\Delta^9$  THC (naturally occurring in the plant in the form of  $\Delta^9$  THCA) and a further chemovar, designated G5 or "high CBD" chemovar produces >90% total cannabinoid content as CBD (naturally occurring in the plant in the form of

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CBDA). Other chemovars yield significant amounts of the minor cannabinoids  $\Delta^9$  THCV (G9 chemovar), CBG (G41 chemovar) and CBC (G80 chemovar). Alternative varieties can be obtained - see for example, Common  
5 cannabinoids phenotypes in 350 stocks of cannabis, Small and Beckstead, Lloydia vol 36b, 1973 p144-156 - and bred using techniques well known to the skilled man to maximise cannabinoid content.

#### 10 Solvents

All solvents used in the isolation and analysis of the cannabinoids; n-pentane, hexane, chloroform, dichloromethane, di-ethyl ether, acetonitrile, water, methanol and glacial acetic acid were, unless  
15 otherwise stated, of chromatographic or A.R. grade.

#### Standards

Reference materials from Sigma were used as standards in the analysis of extracts, intermediates  
20 and finished products, these were:  $\Delta^9$  THC in methanol BN 10601/B (ca. 1 mg/ml) and CBD in methanol BN 10601/C (ca. 1 mg/ml).

#### Solvent extraction step

25 For preparation of  $\Delta^9$  THCA and CBDA samples of G1, THC cannabis chemovar (100 g) and G5, CBD cannabis chemovar (100 g) were extracted twice with 0.1 % v/v glacial acetic acid in hexane (A.R. grade) at a solvent:herb ratio of 15:1. The resulting extracts  
30 were filtered and then solvent removed by rotary evaporation to yield crude extracts enriched in the respective cannabinoid acids and suitable for further processing.

35 For preparation of cannabigerol (CBG) and cannabichromene (CBC) samples of G41, CBG cannabis chemovar (100 g) and G80, CBC cannabis chemovar (100 g) were decarboxylated at 120°C for 1 hour and then extracted twice with hexane at a solvent:herb ratio of  
40 15:1. Following the removal of solvent, this yielded

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a crude extract enriched in the respective compounds  
CBG and CBC and suitable for further processing.

For preparation of  $\Delta^9$  THC and  $\Delta^9$  THCV ethanolic  
solutions of botanical drug substances were prepared,  
respectively, from high THC and high THCV cannabis  
chemovars according to the following process:

harvest cannabis plant material, dry, reduce particle  
size by milling to less than 2000  $\mu\text{m}$

↓

for  $\Delta^9$  THC decarboxylate milled plant material by  
heating to approximately 105°C for 15 minutes,  
followed by approximately 145°C for minimum of 55  
minutes (NB decarboxylation conditions may be varied  
depending on nature of target cannabinoid)

↓

extract with liquid carbon dioxide ( $\text{CO}_2$ ) [Food Grade]  
for up to 10 hours Conditions: Approximately 60 bar  $\pm$   
10 bar pressure and 10°C  $\pm$  5°C

↓

Removal of  $\text{CO}_2$  by depressurisation to recover crude  
extract

↓

"Winterisation"-Dissolution of crude extract in  
ethanol followed by chilling solution  
(-20°C  $\pm$  5°C/up to 52hours) to precipitate unwanted  
waxes

↓

Removal of unwanted waxy material by cold filtration  
(20mm filter)

↓

ethanolic solution of BDS  
(Stored at -20°C  $\pm$  5°C)

Extraction using liquid  $\text{CO}_2$  is carried out under  
sub-critical conditions at a temperature of  
approximately 10°C  $\pm$  5°C using a pressure of  
approximately 60 bar  $\pm$  10bar. Decarboxylated plant  
material is packed into a single column and exposed to

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liquid CO<sub>2</sub> under pressure for approximately 8 hours,  
CO<sub>2</sub> mass flow 1250kg/hr  $\pm$ 20%.

5       Following depressurisation and venting off of the  
CO<sub>2</sub> the crude BDS extract is collected into sealed  
vessels. The crude BDS extract is held at -20°C  $\pm$   
5°C.

10       The crude BDS extract contains waxes and long  
chain molecules. Removal is by "winterisation",  
whereby the crude BDS extract is warmed to e.g. 40°C  $\pm$   
4°C to liquefy the material. Ethanol is added in the  
ratio of 2:1 ethanol volume to weight of crude BDS  
extract. The ethanolic solution is then cooled to  
15       -20°C  $\pm$  5°C and held at this temperature for  
approximately 48 hours.

20       On completion of the winterisation the  
precipitate is removed by cold filtration through a  
20µm filter, to give an ethanolic solution of the BDS.

25       Preliminary charcoal clean-up may be carried out  
by passing the ethanolic BDS solution (500 mg/ml)  
through a disposable plastic column (130 mm x 27 mm  
i.d) packed with activated charcoal (decolourcarb DCL  
GDC grade, from Sutcliffe Speakman Carbons, 15.4 g per  
unit). Absolute ethanol B.P. (Hayman) is used as the  
solvent.

30       Ethanol and any water that may be present are  
removed by evaporation, e.g. rotary evaporation or  
thin film evaporation under reduced pressure (60°C  $\pm$   
2°C, with vapour at 40°C  $\pm$  2°C /172 mbar and 72  
mbar $\pm$ 4mbar). The resulting product may be applied  
35       directly to the chromatography column.

#### Column chromatography step

40       Low pressure column chromatography separations  
were carried out using a glass column (length x  
internal diameter = 1560 mm x 24 mm), packed with  
Sephadex LH-20™ (Fluka). The column length:internal

- 37 -

diameter ratio was therefore 65:1. A 2:1 chloroform/dichloromethane mixture was used as eluant.. Eluate was collected as 50 ml fractions.

5 For purification of  $\Delta^9$  THCA and CBDA approximately 20 ml of crude extract containing the equivalent of 100 g herb was applied to a glass column (dimensions: length 1560 mm x internal diameter 24 mm), packed with 400 g of Sephadex LH-20™ stationary  
10 phase, as described above. The qualitative composition of eluted fractions was monitored by TLC.

For the purification of  $\Delta^9$  THC, 2.5 g of charcoal purified BDS (THC) extract was processed through the  
15 above low pressure chromatography system, (i.e. stationary phase:sample ratio of 160:1). Eluted fractions were analysed for  $\Delta^9$  THC content by TLC.

For purification of CBG and CBC approximately 20 ml of  
20 crude extract containing the equivalent of 100 g herb was applied to a glass column (dimensions: length 1560 mm x internal diameter 24 mm), packed with 400 g of sephadex stationary phase.

25 For the purification of  $\Delta^9$  THCV, 3 g of charcoal purified BDS (THCV) extract was processed through the above low pressure chromatography system, (i.e. stationary phase:sample ratio of 133:1).

30 Solvent treatment steps

Steps of re-dissolving extracts in the first and second solvents, filtering to remove insoluble material and removing solvent by rotary evaporation are carried out according to standard laboratory  
35 procedures, such as would be known to those skilled in the art.

TLC analysis

40 The qualitative composition of fractions eluted from the chromatography column and other intermediates was monitored by TLC.

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TLC uses both retention time and characteristic spot colour to effectively identify the cannabinoid/cannabinoid acid components in a complex mixture. Methanolic solutions of the fractions eluted from the chromatographic column are prepared for TLC analysis. An aliquot is spotted onto a TLC plate, alongside suitable reference samples (e.g. for at least  $\Delta^9$  THC and CBD). Following exposure to Fast Blue B reagent, THC and THCA present as pink spots, while CBD and CBDA are orange in colour. Neutrals can be distinguished from the acids by comparison of the R<sub>f</sub> value to that obtained for the standards. Identity is confirmed by comparison of R<sub>f</sub> and colour of the sample spot, to that obtained for the appropriate standard.

A typical TLC protocol is as follows:

a) Materials and methods

Equipment:

Application device capable of delivering an accurately controlled volume of solution i.e 1  $\mu$ l capillary pipette or micro litre syringe.

TLC development tank with lid

Hot air blower

Silica gel G TLC plates (SIL N-HR/UV<sub>254</sub>), 200  $\mu$ m layer with fluorescent indicator on polyester support.

Dipping tank for visualisation reagent.

Mobile phase 80% petroleum ether 60:80/20% Diethyl ether.

Visualisation reagent 0.1% w/v aqueous Fast Blue B salt BN (Sigma Corp) (100mg in 100ml de-ionised water).

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An optional method is to scan  
at UV 254 and 365 nm.

b) Sample preparation

i) Herbal raw material

Approximately 200mg of finely ground, dried cannabis  
is weighed into a 10ml volumetric flask. Make up to  
volume using methanol:chloroform (9:1) extraction  
solvent.

Extract by ultrasound for 15 minutes. Decant  
supernatant and use directly for chromatography.

ii) Eluted column fractions and intermediate extracts  
are dissolved in methanol then used directly.  
Suitable dilutions may be determined empirically.

iii) Final products

The final products (pure cannabinoids or enriched  
extracts) are dissolved in methanol to a suitable  
concentration (which may be determined empirically)  
then used directly for chromatography. All sample  
preparations should produce a final concentration of  
about 0.5 mg/ml.

iv) Botanical drug substance

Accurately weigh approximately 50 mg of botanical drug  
substance into a 25 ml volumetric flask. Dissolve to  
make volume with HPLC grade methanol.

c) Standards

0.1 mg/ml  $\Delta^9$ -THC in methanol (Sigma).  
0.1 mg/ml CBD in methanol (Sigma).

The standard solutions are stored frozen at -20°C



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between uses and are used for up to 12 months after initial preparation.

d) Test solutions and method

Apply to points separated by a minimum of 10mm.

- i) either 5  $\mu$ l of herb extract or 1  $\mu$ l of pure cannabinoid/enriched extract solution or 1  $\mu$ l of diluted column eluate as appropriate,
- ii) 5  $\mu$ l of 0.1 mg/ml  $\Delta^9$ -THC in methanol standard solution,
- iii) 5  $\mu$ l of 0.1mg/ml CBD in methanol standard solution.

Dry the prepared plate with a hot air blower.

Place the base of the TLC plate in a development tank containing the mobile phase and saturated with vapour.

Elute the TLC plate through a distance of 8cm, then remove the plate. Allow solvent to evaporate from the plate and then repeat the elution for a second time (double development). Remove plate and allow it to dry in air.

The entire plate is briefly immersed in the Fast Blue B reagent until the characteristic red/orange colour of cannabinoids begins to develop. The plate is removed and allowed to dry under ambient conditions in the dark.

Cannabinoids will give an orange-purple colour:

|                                   |      |                          |
|-----------------------------------|------|--------------------------|
| Cannabidiol                       | CBD  | orange (fastest running) |
| $\Delta^9$ Tetrahydrocannabinol   | THC  | pink                     |
| Cannabinol                        | CBN  | purple                   |
| Cannabichromene                   | CBC  | pink purple              |
| Cannabigerol                      | CBG  | orange                   |
| $\Delta^9$ tetrahydrocannabivarin | THCV | purple                   |

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The corresponding acids form streaks of the same colour as the neutral component spots. The acids run at lower  $R_f$ .

5     HPLC analysis

The composition of the isolated products may be determined by HPLC analysis.

10     A typical HPLC assay for  $\Delta^9$  THC,  $\Delta^9$  THCA, CBD, CBDA and CBN may be carried out as follows:

a)   Materials and methods

Chromatography Equipment and conditions:

|    |                  |  |
|----|------------------|--|
| 15 | Equipment        | Agilent (HP)1100 HPLC system with variable wavelength UV detector or diode array detector. |
|    | HPLC Column      | Discovery C8 5 $\mu$ m 15cm x 0.46cm   |
|    | Pre-Column       | Kingsorb C18 5 $\mu$ m 3cm x 0.46cm  |
| 20 | Mobile Phase     | Acetonitrile : Methanol : 0.25% w/v acetic acid (16:7:6 by volume)                         |
|    | Column Temp      | 25°C   |
|    | Flow Rate        | 1.0ml min <sup>-1</sup>  |
|    | Detection        | 220nm 600mA f.s.d.    Second wavelength  |
| 25 |                  | 310nm  |
|    | Injection Volume | 10 $\mu$ l   |
|    | Run Time         | 20-25 minutes (may be extended for samples containing small amount of late-eluting peaks)  |
| 30 | Elution Order    | CBD, CBDA, $\Delta^9$ THCV, CBN, $\Delta^9$ THC, CBC, $\Delta^9$ THCA                      |

b)   Sample preparation

35     Samples of "pure" cannabinoids/cannabinoid acids and enriched extracts are diluted in methanol prior to HPLC analysis. Optimal dilutions may be determined empirically.

40     Herbal cannabis samples are prepared by taking a 100mg

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sample and treating this with 5 or 10ml of Methanol/Chloroform (9/1 w/v). The dispersion is sonicated in a sealed tube for 10 minutes, allowed to cool and an aliquot is centrifuged and suitably diluted with methanol prior to chromatography.

c) Standards

Stock standard solutions of CBD, CBN and  $\Delta^9$  THC in methanol at approximately 1mg ml<sup>-1</sup> are stored at -20°C. Diluted working standards (0.1 mg/ml for  $\Delta^9$  THC and CBD and 0.01 mg/ml for CBN) are prepared in methanol from the stock standards and stored at -20°C (maximum period of twelve months after initial preparation). After preparation, standard solutions must be aliquoted into vials to reduce the amount of standard exposed to room temperature. Prior to use in an HPLC sample assay, the required number of standard vials are removed and allowed to equilibrate to room temperature.

Injection of each standard is made in triplicate prior to the injection of any test solution. At suitable intervals during the processing of test solutions, repeat injections of standards are made. In the absence of reliable CBDA and  $\Delta^9$  THCA standards, these compounds are analysed using respectively the CBD and  $\Delta^9$  THC standard response factors.

d) Test solutions

Diluted test solutions are made up in methanol and should contain analytes in the linear working range of from 0.02-0.2 mg/ml.

e) Chromatography Acceptance Criteria:

The following acceptance criteria are applied to the results of each sequence as they have been found to result in adequate resolution of all analytes (including the two most closely eluting analytes CBD

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and CBDA)

Table 1- Retention time windows and Relative Retention Time (RRT) to  $\Delta^9$  THC for each analyte

| Cannabinoid     | Retention time (minutes) | RRT (THC) |
|-----------------|--------------------------|-----------|
| CBD             | 5.1-5.8                  | 0.58      |
| CBN             | 7.4-8.3                  | 0.83      |
| $\Delta^9$ THC  | 9.0-10.0                 | 1.00      |
| CBDA            | 5.5-6.2                  | 0.615     |
| $\Delta^9$ THCV | 5.9-6.2                  | 0.645     |
| CBC             | 11.6-12.8                | 1.30      |
| $\Delta^9$ THCA | 14.6-16.0                | 1.605     |

Table 2- Peak Shape (Symmetry Factor according to British Pharmacopoeia method)

| Cannabinoid    | Symmetry factor |
|----------------|-----------------|
| CBD            | <1.30           |
| CBN            | <1.25           |
| $\Delta^9$ THC | <1.35           |

#### f) Data Processing

Cannabinoids can be subdivided into neutral and acidic-the qualitative identification can be performed using the DAD dual wavelength mode. Acidic cannabinoids absorb strongly in the region of 220nm-310nm. Neutral cannabinoids only absorb strongly in the region of 220nm.

Routinely, only the data recorded at 220nm is used for quantitative analysis.

The DAD can also be set up to take UV spectral scans of each peak, which can then be stored in a spectral

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library and used for identification purposes.

Data processing for quantitation utilises batch processing software on the Hewlett Packard Chemstation.

g) calculation:

Chromatographic purity of cannabinoid samples is calculated as a % of total cannabinoid content by area normalization.

#### Capillary gas chromatography (GC) analysis

##### a) Chromatography equipment and conditions

|               |   |
|---------------|---|
| Equipment     | Agilent (HP) 5890 or 6890 GLC system with HP7673 Autosampler and FID detector                             |
| GLC column    | SE54 (EC5) 30m x 0.32mm i.d. (Alltech) phase thickness 0.25 $\mu\text{m}$                                 |
| Flow rate     | Constant pressure (10.3 psi). Normal initial flow rate 34cm sec <sup>-1</sup> (2.0 ml min <sup>-1</sup> ) |
| Column oven   | 70°C initially then ramp 5°C min <sup>-1</sup> to 250°C. Hold at 250°C for 15 minutes.                    |
| Injector temp | 250°C   |
| Detector temp | 325°C   |
| Injection Vol | 1 $\mu\text{l}$ , split ratio 2.5:1   |
| Run time      | 45 minutes  |
| Fuel gases    | Hydrogen 40 ml min <sup>-1</sup><br>Air 450 ml min <sup>-1</sup><br>Helium 45 ml min <sup>-1</sup>        |

##### b) Standard preparation

Stock standard solutions of CBD, CBN and  $\Delta^9$  THC in methanol at approximately 1mg ml<sup>-1</sup> are stored at -20°C. Diluted working standards (0.1 mg/ml for  $\Delta^9$  THC and CBD and 0.01 mg/ml for CBN) are prepared in

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methanol from the stock standards and stored at -20°C (maximum period of twelve months after initial preparation). Allow an aliquot pipetted into an autosampler vial to equilibrate to room temperature prior to use in a GC assay.

c) Sample preparation

Samples of final products, i.e. "pure" cannabinoids/cannabinoid acids and enriched extracts are diluted in methanol prior to HPLC analysis. Optimal dilutions may be determined empirically.

Cannabis plant material samples are prepared by taking 100mg chopped dried material and treating this with 5 or 10ml of Methanol/Chloroform (9:1 v/v). Extract the sample in an ultrasonic bath for 15 minutes and allow to stand in the dark for 18 hours.

d) Chromatography procedure

Standard solutions are used to provide quantitative and retention time data. These can be typically injected in triplicate prior to the injection of any sample solutions and then singularly at suitable intervals during the run, with a maximum of 10 test samples in between standards.

Table 3-Retention times

|                |                   |
|----------------|-------------------|
| THCV           | 33.7-34.5 minutes |
| CBD            | 35.6-36.3 minutes |
| $\Delta^9$ THC | 37.2-38.1 minutes |
| CBN            | 38.5-39.1 minutes |

Example 1 - Preparation of  $\Delta^9$  THCA

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## Summary of process:

5 Extract THC herb (G1 chemovar) with 0.1% v/v acetic  
acid in hexane.  
↓  
Filter and remove solvent from filtrate on rotary  
evaporator.  
↓  
10 Pass a solution of the resulting THCA enriched extract  
through a column packed with Sephadex LH20, eluting  
with 2:1 chloroform/dichloromethane.  
↓  
15 Collect THCA rich fractions and remove solvent by  
rotary evaporation.  
↓  
Re-dissolve crude THCA in methanol and remove  
insoluble residue by filtration.  
↓  
20 Remove solvent from filtrate by rotary evaporation.  
↓  
Re-dissolve crude THCA in pentane and remove insoluble  
residue by filtration.  
↓  
25 Remove solvent from filtrate by rotary evaporation.  
↓  
 $\Delta^9$  THCA crystals

## Results:

30 Yield:  
100 g of G1 chemovar yields approx 5 g of purified  $\Delta^9$   
THCA

35 Characteristics:  
Pale yellow crystalline solid.

Chromatographic purity = 98% by area normalization.

40 CBD < 0.5% w/w  
THC = 1.0% w/w

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CBN < 1.0% w/w

Melting point = 70°C (with decomposition).

5     Material slowly decarboxylates in solution  
       $\Delta^9$  THCA  $\rightarrow$   $\Delta^9$  THC + CO<sub>2</sub>

Example 2-Preparation of CBDA

10

Summary of process:

Extract CBD herb (G5 chemovar) with 0.1% v/v acetic  
acid in hexane.

15

↓  
Filter and remove solvent from filtrate on rotary  
evaporator.

20

↓  
Pass a solution of the resulting CBDA enriched extract  
through a column packed with Sephadex LH20, eluting  
with 2:1 chloroform/dichloromethane.

↓  
Collect CBDA rich fractions and remove solvent by  
rotary evaporation.

25

↓  
Re-dissolve crude CBDA in methanol and remove  
insoluble residue by filtration.

30

↓  
Remove solvent from filtrate by rotary evaporation.  
↓  
Re-dissolve crude CBDA in pentane and remove insoluble  
residue by filtration.

35

↓  
Remove solvent from filtrate by rotary evaporation.

↓  
i) CBDA crystals or ii) CBDA solution

For i) above:

40

Yield:



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100 g of G5 chemovar yields approx 5 g of purified CBDA.

Characteristics:

5 Pale yellow crystalline solid

Melting Point = 45-48°C

10 Chromatographic purity = 94 % CBDA by area  
normalisation with reference to Figure 4

\*CBD 3 %.

THCA non detected i.e. < 0.1 %

THC non detected i.e. < 0.1 %

15

Material slowly decarboxylates in solution  
CBDA  $\rightarrow$  CBD + CO<sub>2</sub>

20 \* As CBDA does not co-elute with CBD during processing  
of the extract in the low pressure column  
chromatography method employed, the detected CBD is  
likely to be formed from the breakdown of the CBDA  
during processing and analysis. This undesirable  
decarboxylation of the purified material might be  
25 minimised by manipulation of CBDA at sub-ambient  
temperatures.

For ii) above:

30 Characteristics:

Clear colourless solution

35 Chromatographic purity=98.9% CBDA by area  
normalisation with reference to Figure 5

THCA 0.28%

40

Example 3 - Preparation of  $\Delta^9$  THC

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## Summary of process:

5        Ethanolic solution of BDS (approx 400 mg/ml) passed  
         through a column of activated charcoal, and eluate  
         collected.

↓

10        Remove solvent by rotary evaporation to give THC  
         enriched fraction.

↓

10        Pass a solution of the resulting THC enriched extract  
         through a column packed with Sephadex LH20, eluting  
         with 2:1 chloroform/dichloromethane.

↓

15        Collect THC rich fractions and remove solvent by  
         rotary evaporation.

↓

20        Re-dissolve crude THC in methanol and remove insoluble  
         residue by filtration.

↓

20        Remove solvent from filtrate by rotary evaporation.

↓

25        Re-dissolve crude THC in pentane and remove insoluble  
         residue by filtration.

↓

25        Remove solvent from filtrate by rotary evaporation.

↓

$\Delta^9$  THC SEMI-SOLID

30

## Yield:

3.5 g of  $\Delta^9$  THC BDS yields approx 1.5 g of purified  $\Delta^9$   
THC.

35

## Characteristics:

Clear semi-solid which rapidly takes on a purple  
colour when exposed to air.

(This colour change is reversible when the material is  
redissolved in a suitable solvent).

40

Chromatographic purity > 99%  $\Delta^9$  THC by area

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normalization.

Chromatographic purity superior to commercially available  $\Delta^9$  THC Sigma standard

5

CBD non detected i.e. < 0.1%

CBN non detected i.e. < 0.1%

10

Identity confirmed by HPLC, GC and TLC retention behaviour compared to  $\Delta^9$  THC Sigma standard.

#### Example 4-Preparation of $\Delta^9$ THCV

15

Summary of process:

Ethanollic solution of BDS, derived from G9 chemovar, passed through column of activated charcoal, and eluate collected.

20

↓

Remove solvent by rotary evaporation to give enriched cannabinoid extract.

↓

25

Pass a solution of the resulting concentrated extract through a column packed with Sephadex LH20 and eluting with 2:1 chloroform/dichloromethane.

↓

Collect THCV rich fractions and remove solvent by rotary evaporation.

30

↓

Re-dissolve crude THCV enriched fractions in methanol and remove insoluble residue by filtration.

↓

Remove solvent from filtrate by rotary evaporation.

35

↓

Re-dissolve crude THCV enriched fractions in pentane and remove insoluble residue by filtration.

↓

Remove solvent from filtrate by rotary evaporation.

40

↓

Crystalline THCV

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Yield:

4.0 g of  $\Delta^9$  THCV BDS yields approx 1.3 g of purified  $\Delta^9$  THCV.

Characteristics:

Off white crystals which rapidly take on a purple colour when exposed to air. This colour change is reversible when the crystals are redissolved.

Chromatographic purity >99% by area normalization.

CBD non detected i.e. < 0.1 %

THC 0.5 %

CBN non detected i.e. < 0.1 %

Superior to BDS THCV, which contains 75 % THCV & 17 % THC as % of total cannabinoids, for studies of chemistry and pharmacology of THCV.

Identity confirmed by HPLC & GC retention times versus THCV fraction previously authenticated by GC-MS.

#### Example 5-Preparation of cannabigerol (CBG)

Summary of process:

Extract decarboxylated G41 chemovar with hexane.

↓

Filter and remove solvent from filtrate on rotary evaporator.

↓

Pass a solution of the resulting concentrated extract through a column packed with Sephadex LH20 and eluting with 2:1 chloroform/dichloromethane.

↓

Collect CBG rich fractions and remove solvent by rotary evaporation.

↓

Re-dissolve crude CBG enriched fractions in methanol

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and remove insoluble residue by filtration.

↓

Remove solvent from filtrate by rotary evaporation.

↓

5 Re-dissolve crude CBG enriched fractions in pentane  
and remove insoluble residue by filtration.

↓

Remove solvent from filtrate by rotary evaporation.

↓

10 i) Highly enriched CBG extract or ii) CBG solution

↓

Flash chromatography

For i) above:

15 Yield:

100 g of G41 chemovar yields approx 300 mg of CBG  
enriched fraction.

Characteristics:

20 Orange/yellow semi-solid.

Identification by GC retention index relative to THC &  
CBD standards [ref: Brenneisen, R. & El Sohly, M.A.,  
"Chromatographic & spectroscopic Profiles of Cannabis  
25 of Different Origins: Part I," Journal of Forensic  
Sciences, JFSCA, vol.33, No.6, pp.1385-1404, 1988].

Chromatographic purity >92% by area normalization with  
reference to Figure 14.

30

CBD non-detected i.e. <0.1%

THC 0.1%

CBN non-detected i.e. <0.1%

35

For ii) above:

Characteristics:

Clear colourless solution

40

Chromatographic purity=97.2% CBG by area normalisation  
with reference to Figure 15

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CBD 1.66%

CBN non-detected i.e. &lt;0.1%

5 Following flash chromatography of product ii):  
Characteristics:  
Clear colourless solution

10 Chromatographic purity=99.9% CBG by area normalisation  
with reference to Figure 16

Example 6-Preparation of cannabichromene (CBC)

15 Summary of process:

Extract decarboxylated G80 chemovar with hexane.

↓

20 Filter and remove solvent from filtrate on rotary  
evaporator.

↓

Pass a solution of the resulting concentrated extract  
through a column packed with Sephadex LH20 and eluting  
with 2:1 chloroform/dichloromethane.

25 ↓

Collect CBC rich fractions and remove solvent by  
rotary evaporation.

↓

30 Re-dissolve crude CBC enriched fractions in methanol  
and remove insoluble residue by filtration.

↓

Remove solvent from filtrate by rotary evaporation.

↓

35 Re-dissolve crude CBC enriched fractions in pentane  
and remove insoluble residue by filtration.

↓

Remove solvent from filtrate by rotary evaporation.

↓

40 i) Highly enriched CBC extract or ii) CBC solution

For i) above:

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Yield:

100 g of G80 chemovar yields approx 300 mg of CBC  
enriched fraction.

- 5      Characteristics:  
Orange/yellow semi-solid.

Identification by GC retention index relative to THC &  
CBD standards [ref: Brenneisen, R. & El Sohly, M.A.,  
10      "Chromatographic & spectroscopic Profiles of Cannabis  
of Different Origins: Part I," Journal of Forensic  
Sciences, JFSCA, vol.33, No.6, pp.1385-1404, 1988]..

Chromatographic purity >85% by area normalization with  
15      reference to Figure 19.

CBD 1.0 %  
THC 0.3 %  
CBN 0.1 %

20      For ii) above:  
Characteristics:  
Clear colourless solution

25      Chromatographic purity=99.6% CBC by area normalisation  
with reference to Figure 20

CBD 0.12%  
CBN 0.09%

30

Claims

1. A method of obtaining a substantially pure cannabinoid or cannabinoid acid or a product enriched in a given cannabinoid or cannabinoid acid from a plant material, comprising:
- 5 i) obtaining an extract containing a cannabinoid or cannabinoid acid from a plant material;
- 10 ii) subjecting the extract of step (i) to a chromatographic step to produce a partially purified extract;
- 15 iii) dissolving the partially purified extract in a first solvent, removing any insoluble material therefrom and removing the solvent; and
- 20 iv) dissolving the product obtained in step iii) in a second solvent, removing any insoluble material therefrom, and removing the solvent to obtain the substantially pure cannabinoid or cannabinoid acid or the product enriched in a given cannabinoid or cannabinoid acid, wherein the first and second solvents are different, and wherein one of the first or second solvents is a solvent which is substantially more polar than the cannabinoid/cannabinoid acid which it is desired to purify, and the other solvent is a solvent which is substantially less polar than the cannabinoid/cannabinoid acid which it is desired to purify.
- 25
2. A method according to claim 1 wherein one of the solvents is an alcohol.
- 30
3. A method according to claim 2 wherein one of the solvents is methanol.
- 35
4. A method according to any one of claims 1 to 3 wherein one of the solvents is a straight or branched chain C5-C12 alkane.
- 40
5. A method according to claim 4 wherein one of the solvents is pentane.



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6. A method according to claim 5 wherein one of the solvents is pentane and the other solvent is methanol.

5 7. A method according to any one of the preceding claims wherein the extract containing a cannabinoid or cannabinoid acid obtained in step (i) is prepared by a process comprising solvent extraction of the plant material.

10 8. A method according to claim 7 wherein step (i) comprises dissolving the plant material in an extraction solvent, removing any insoluble material from the resultant solution and removing the solvent to form an extract containing a cannabinoid or  
15 cannabinoid acid.

9. A method according to claim 7 or claim 8 wherein the extraction solvent is a non-polar solvent, ethanol, methanol or carbon dioxide.  
20

10. A method according to claim 9 wherein the non-polar solvent comprises a straight or branched chain C5-C12 alkane.  
25

11. A method according to claim 10 wherein the non-polar solvent is hexane.

12. A method according to claim 7 or claim 8, wherein the extraction solvent is acidified.  
30

13. A method according to claim 12 wherein the extraction solvent is an acidified non-polar solvent.

14. A method according to claim 13 wherein the extraction solvent is an acidified straight or branched chain C5-C12 alkane.  
35

15. A method according to claim 14 wherein the extraction solvent is 0.1% v/v acetic acid in hexane.  
40

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16. A method according to any one of claims 1 to 15, which includes a further step, prior to step (i), of decarboxylating the plant material.

5 17. A method according to any one of claims 1 to 6 wherein the extract containing a cannabinoid or cannabinoid acid obtained in step (i) comprises a botanical drug substance derived from the plant material.

10 18. A method according to claim 17 wherein the botanical drug substance is prepared by a process comprising solvent extraction of the plant material.

15 19. A method according to claim 18 wherein the botanical drug substance is prepared by extraction with carbon dioxide.

20 20. A method according to claim 19 wherein the botanical drug substance is prepared by a process comprising extraction with carbon dioxide (CO<sub>2</sub>), followed by a secondary extraction step to remove a proportion of the non-target materials.

25 21. A method according to claim 20 wherein the secondary extraction step is ethanolic precipitation.

30 22. A method according to claim 20 or claim 21 wherein the process for preparing the botanical drug substance further includes a charcoal clean-up step.

23. A method according to claim 22 wherein the botanical drug substance is prepared by a process comprising:

- 35 i) optional decarboxylation of the plant material,  
ii) extraction with liquid CO<sub>2</sub>, to produce a crude botanical drug substance,  
iii) precipitation with C1-C5 alcohol to reduce the proportion of non-target materials,  
40 iv) removal of the precipitate,  
v) treatment with activated charcoal, and

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vi) evaporation to remove C1-C5 alcohol and water, thereby producing a final botanical drug substance.

24. A method according to any one of the preceding claims wherein the chromatographic step comprises column chromatography.

25. A method according to any one of the preceding claims wherein the chromatographic step is based on molecular sizing and polarity.

26. A method according to claim 25 wherein the chromatographic step is carried out using a Sephadex™ LH-20 matrix.

27. A method according to claim 26 wherein the chromatographic step is carried out using a 2:1 mixture of chloroform/dichloromethane as solvent.

28. A substantially pure preparation of  $\Delta^9$  tetrahydrocannabinolic acid ( $\Delta^9$  THCA) having a chromatographic purity of greater than 95%, more preferably greater than 96%, more preferably greater than 97% or most preferably greater than 98% by area normalisation of an HPLC profile.

29. A preparation according to claim 28 which is a pale yellow crystalline solid at room temperature.

30. A preparation according to claim 28 or claim 29 which comprises less than 2%, preferably less than 1.5%, most preferably 1% or less  $\Delta^9$  THC (w/w).

31. A preparation according to any one of claims 28 to 30 which comprises less than 2%, more preferably less than 1.5%, more preferably less than 1% or most preferably less than 0.5% CBD (w/w).

32. A preparation according to any one of claims 28 to 31 which comprises less than 2%, more preferably less than 1.5%, or most preferably less than 1% CBN

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(w/w) .

33. A preparation according to any one of claims 28 to 32 which is obtainable from cannabis plant material using a method comprising:

- i) preparing an extract of the cannabis plant material with 0.1% v/v acetic acid in hexane,
- ii) filtering the resultant extract and removing solvent from filtrate by rotary evaporation to form an extract enriched in  $\Delta^9$  THCA,
- iii) passing a solution of the resulting  $\Delta^9$  THCA enriched extract through a column packed with Sephadex-LH20™, eluting with 2:1 chloroform/dichloromethane,
- iv) collecting  $\Delta^9$  THCA rich fractions eluted from the column and removing solvent by rotary evaporation,
- v) re-dissolving the crude  $\Delta^9$  THCA obtained in step iv) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,
- vi) re-dissolving the product of step v) in pentane, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation to produce  $\Delta^9$  THCA crystals.

34. A substantially pure preparation of  $\Delta^9$  tetrahydrocannabinolic acid ( $\Delta^9$  THCA) substantially as described herein and having an HPLC profile substantially as shown in Figure 2.

35. A substantially pure preparation of cannabidiolic acid (CBDA) having a chromatographic purity of greater than 90%, more preferably greater than 92% or most preferably greater than 94% by area normalisation of an HPLC profile.

36. A preparation according to claim 35 which is a pale yellow crystalline solid at room temperature.

37. A preparation according to claim 35 or claim

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36 comprising 5% or less, preferably 4.5% or less, more preferably 4% or less, more preferably 3.5% or less or most preferably 3% or less CBD (w/w).

5           38. A preparation according to any one of claims 35 to 37 comprising less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1%  $\Delta^9$  THCA (w/w).

10           39. A preparation according to any one of claims 35 to 38 comprising less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most  
15 preferably less than 0.1%  $\Delta^9$  THC (w/w).

20           40. A substantially pure preparation of cannabidiolic acid (CBDA) having a chromatographic purity of greater than 94%, more preferably greater than 96% or most preferably greater than 98% by area normalisation of an HPLC profile.

25           41. A preparation according to claim 40 which is a clear colourless solution at room temperature.

30           42. A preparation according to claim 40 or claim 41 comprising 3% or less, preferably 2% or less, more preferably 1%, or most preferably less than 0.1% CBD (w/w).

35           43. A preparation according to any one of claims 40 to 42 comprising less than 0.8%, preferably less than 0.6%, more preferably less than 0.3%  $\Delta^9$  THCA (w/w).

40           44. A preparation according to any one of claims 40 to 43 comprising less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1%  $\Delta^9$  THC (w/w).

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45. A preparation according to any one of claims 35 to 44 which is obtainable from cannabis plant material using a method comprising:

- 5 i) preparing an extract of the cannabis plant material with 0.1% v/v acetic acid in hexane,
- ii) filtering the resultant extract and removing solvent from filtrate by rotary evaporation to form an extract enriched in CBDA,
- 10 iii) passing a solution of the resulting CBDA enriched extract through a column packed with Sephadex-LH20™, eluting with 2:1 chloroform/dichloromethane,
- iv) collecting CBDA rich fractions eluted from the column and removing solvent by rotary evaporation,
- 15 v) re-dissolving the crude CBDA obtained in step iv) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,
- vi) re-dissolving the product of step v) in pentane,
- 20 removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation to produce CBDA crystals.

46. A substantially pure preparation of  
25 cannabidiolic acid (CBDA) substantially as described herein and having an HPLC profile substantially as shown in Figure 4.

47. A substantially pure preparation of  
30 cannabidiolic acid (CBDA) substantially as described herein and having an HPLC profile substantially as shown in Figure 5.

48. A substantially pure preparation of  $\Delta^9$   
35 tetrahydrocannabinol ( $\Delta^9$  THC) having a chromatographic purity of >99% by area normalisation of an HPLC profile.

49. A preparation according to claim 48 which is  
40 a semi-solid at room temperature.

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50. A preparation according to claim 48 or claim 49 which comprises less than 0.5%, preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1% CBD (w/w).

51. A preparation according to any one of claims 48 to 50 which comprises less than 0.5%, preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1% CBN (w/w).

52. A preparation according to any one of claims 48 to 51 which is obtainable from cannabis plant material using a method comprising:

- i) obtaining an ethanolic solution of a botanical drug substance from decarboxylated cannabis plant material,
- ii) passing the solution obtained in step i) through a column of activated charcoal, and collecting the eluate,
- iii) remove solvent from the eluate by rotary evaporation to give a  $\Delta^9$  THC enriched fraction,
- iv) passing a solution of the resulting  $\Delta^9$  THC enriched extract through a column packed with Sephadex LH20, eluting with 2:1 chloroform/dichloromethane,
- v) collecting  $\Delta^9$  THC rich fractions and removing solvent by rotary evaporation,
- vi) re-dissolving the crude  $\Delta^9$  THC prepared in step v) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,
- vii) re-dissolving the crude  $\Delta^9$  THC prepared in step vi) in pentane, removing insoluble residue by filtration and removing solvent from the filtrate by rotary evaporation to give a semi-solid preparation of  $\Delta^9$  THC.

53. A preparation according to claim 52 wherein the ethanolic solution of a botanical drug substance from decarboxylated cannabis plant material is obtained by a method comprising the following steps:

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- i) harvesting cannabis plant material,
- ii) decarboxylation of the plant material,
- iii) extraction with liquid carbon dioxide (CO<sub>2</sub>),
- removal of CO<sub>2</sub> to recover crude extract,
- 5 iv) dissolution of crude extract in ethanol followed by chilling of the solution to precipitate unwanted waxes,
- v) removal of unwanted waxy material by cold filtration.

10

54. A substantially pure preparation of  $\Delta^9$  tetrahydrocannabinol ( $\Delta^9$  THC) substantially as described herein and having an HPLC profile substantially as shown in Figure 8.

15

55. A substantially pure preparation of  $\Delta^9$  tetrahydrocannabivarin ( $\Delta^9$  THCV) having a chromatographic purity of greater than 95%, more preferable greater than 96%, more preferable greater than 97%, more preferable greater than 98%, and most preferable greater than 99% by area normalisation of an HPLC profile.

20

56. A preparation according to claim 55 which is a crystalline solid at room temperature.

25

57. A preparation according to claim 55 or claim 56 which comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1% CBD (w/w).

30

58. A preparation according to any one of claims 55 to 57 which comprises less than 2.0%, preferably less than 1.5%, more preferably less than 1.0% or most preferably 0.5% or less  $\Delta^9$  THC (w/w).

35

59. A preparation according to any one of claims 55 to 58 which comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than

40



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0.2% or most preferably less than 0.1% CBN (w/w).

60. A preparation according to any one of claims 55 to 59 which is obtainable from cannabis plant material using a method comprising:

- i) obtaining an ethanolic solution of a botanical drug substance from cannabis plant material,
- ii) passing the solution obtained in step i) through a column of activated charcoal, and collecting the eluate,
- iii) remove solvent from the eluate by rotary evaporation to give a  $\Delta^9$  THC<sub>V</sub> enriched fraction,
- iv) passing a solution of the resulting  $\Delta^9$  THC<sub>V</sub> enriched extract through a column packed with Sephadex LH20, eluting with 2:1 chloroform/dichloromethane,
- v) collecting  $\Delta^9$  THC<sub>V</sub> rich fractions and removing solvent by rotary evaporation,
- vi) re-dissolving the crude  $\Delta^9$  THC<sub>V</sub> prepared in step v) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,
- vii) re-dissolving the crude  $\Delta^9$  THC<sub>V</sub> prepared in step vi) in pentane, removing insoluble residue by filtration and removing solvent from the filtrate by rotary evaporation to give crystals of  $\Delta^9$  THC<sub>V</sub>.

61. A preparation according to claim 60 wherein the ethanolic solution of a botanical drug substance from decarboxylated cannabis plant material is obtained by a method comprising the following steps:

- i) harvesting cannabis plant material,
- ii) extraction with liquid carbon dioxide (CO<sub>2</sub>), removal of CO<sub>2</sub> to recover crude extract,
- iii) dissolution of crude extract in ethanol followed by chilling of the solution to precipitate unwanted waxes,
- vi) removal of unwanted waxy material by cold filtration.

62. A substantially pure preparation of  $\Delta^9$

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tetrahydrocannabivarin ( $\Delta^9$  THCV) substantially as described herein and having an HPLC profile substantially as shown in Figure 11.

5           63. A product enriched in cannabigerol (CBG) having a chromatographic purity of greater than 90%, preferably greater than 92% by area normalisation of an HPLC profile.

10           64. A product according to claim 63 which is an orange-yellow semi-solid at room temperature.

15           65. A product according to claim 63 or claim 64 which comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1% CBD (w/w).

20           66. A product according to any one of claims 63 to 65 which comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably 0.1% or less  $\Delta^9$  THC (w/w).

25           67. A product according to any one of claims 63 to 66 which comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1% CBN (w/w).

30           68. A substantially pure preparation of cannabigerol (CBG) having a chromatographic purity of greater than 92%, more preferably greater than 94%, more preferably greater than 96% or most preferably greater than 97% by area normalisation of an HPLC profile.

35           69. A preparation according to claim 68 which is a clear colourless solution at room temperature.

40           70. A preparation according to claim 68 or claim

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69 which comprises 4% or less, more preferably 3% or less, or most preferably less than 2% CBD (w/w).

5 71. A preparation according to any one of claims 68 to 70 which comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1%  $\Delta^9$ -THC (w/w).

10 72. A preparation according to any one of claims 68 to 71 which comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2%, or most preferably less than 0.1% CBN (w/w).

15 73. A product according to any one of claims 63 to 72 which is obtainable from cannabis plant material using a method comprising:

20 i) decarboxylating the cannabis plant material,  
ii) preparing an extract of the decarboxylated cannabis plant material with hexane,  
iii) filtering the resultant extract and removing solvent from filtrate by rotary evaporation to form an extract enriched in CBG,

25 iv) passing a solution of the resulting CBG enriched extract through a column packed with Sephadex-LH20™, eluting with 2:1 chloroform/dichloromethane,  
v) collecting CBG rich fractions eluted from the column and removing solvent by rotary evaporation,

30 vi) re-dissolving the crude CBG obtained in step v) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,

35 vii) re-dissolving the product of step vi) in pentane, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation to produce a highly enriched CBG extract or substantially pure cannabigerol.

40 74. A product according to claim 73 wherein the method includes a further step viii) of loading the

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highly enriched CBG extract or substantially pure cannabigerol onto a Chromabond Flash BT 12M silica cartridge column, and eluting with hexane:ethyl acetate (98:2) at a flow rate of approximately 5 ml/min.

75. A product enriched in cannabigerol (CBG) substantially as described herein and having an HPLC profile substantially as shown in Figure 14.

76. A substantially pure preparation of cannabigerol (CBG) substantially as described herein and having an HPLC profile substantially as shown in Figure 15.

77. A substantially pure preparation of cannabigerol (CBG) substantially as described herein and having an HPLC profile substantially as shown in Figure 16.

78. A product enriched in cannabichromene (CBC) having a chromatographic purity of greater than 80%, more preferably greater than 85% by area normalisation of an HPLC profile.

79. A product according to claim 78 which is an orange-yellow semi-solid at room temperature.

80. A product according to claim 78 or claim 79 which comprises less than 5%, preferably less than 4%, more preferably less than 3%, more preferably less than 2% or most preferably 1% or less CBD (w/w).

81. A product according to any one of claims 78 to 80 which comprises less than 2%, preferably less than 1.5%, more preferably less than 1.0%, more preferably less than 0.5% or most preferably 0.3% or less  $\Delta^9$  THC (w/w).

82. A product according to any one of claims 78 to 81 which comprises less than 1%, preferably less

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than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably 0.1% or less CBN (w/w).

5           83. A substantially pure preparation of cannabichromene (CBC) having a chromatographic purity of greater than 85%, more preferably greater than 90%, more preferably greater than 95%, more preferably greater than 98% or most preferably greater than 99%  
10 by area normalisation of an HPLC profile.

84. A preparation according to claim 83 which is a clear colourless solution at room temperature.

15           85. A preparation according to claim 83 or claim 84 which comprises 1% or less, more preferably 0.8% or less, more preferably 0.6% or less, more preferably 0.4% or less or most preferably less than 0.2% CBD (w/w).

20           86. A preparation according to any one of claims 83 to 85 which comprises less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1%  $\Delta^9$ -THC (w/w),

25           87. A preparation according to any one of claims 83 to 86 less than 1%, preferably less than 0.8%, more preferably less than 0.6%, more preferably less than 0.4%, more preferably less than 0.2% or most preferably less than 0.1% CBN (w/w).

30           88. A product according to any one of claims 78 to 87 which is obtainable from cannabis plant material using a method comprising:  
35 i) decarboxylating the cannabis plant material,  
ii) preparing an extract of the decarboxylated cannabis plant material with hexane,  
iii) filtering the resultant extract and removing  
40 solvent from filtrate by rotary evaporation to form an extract enriched in CBC,

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- iv) passing a solution of the resulting CBC enriched extract through a column packed with Sephadex-LH20™, eluting with 2:1 chloroform/dichloromethane,
- 5 v) collecting CBC rich fractions eluted from the column and removing solvent by rotary evaporation,
- vi) re-dissolving the crude CBC obtained in step v) in methanol, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation,
- 10 vii) re-dissolving the product of step vi) in pentane, removing insoluble residue by filtration and removing solvent from filtrate by rotary evaporation to produce a highly enriched CBC extract.

15 89. A product enriched in cannabichromene (CBC) substantially as described herein and having an HPLC profile substantially as shown in Figure 19.

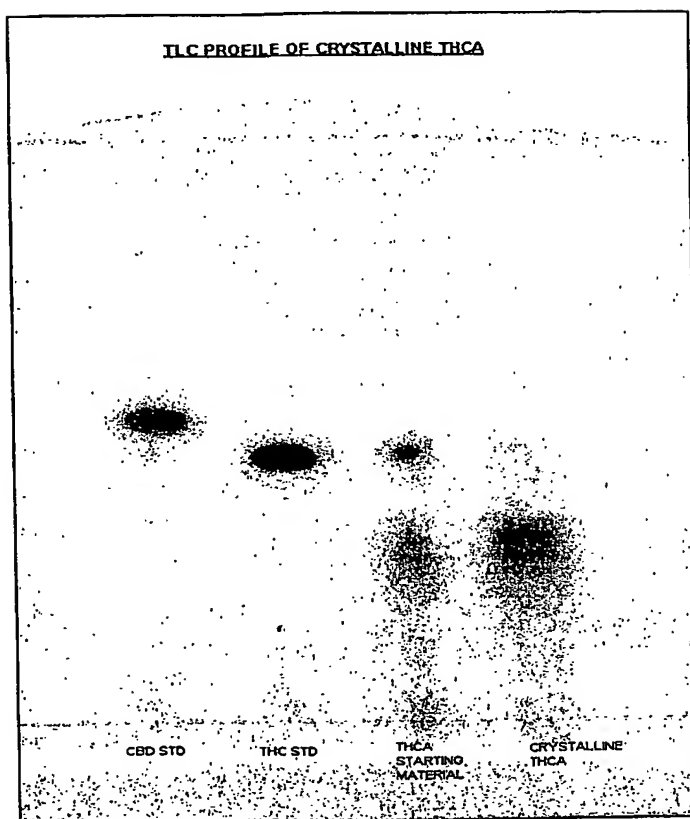
20 90. A substantially pure preparation of cannabichromene (CBC) substantially as described herein and having an HPLC profile substantially as shown in Figure 20.

25 91. A method according to claim 1 which comprises a further step v) of:

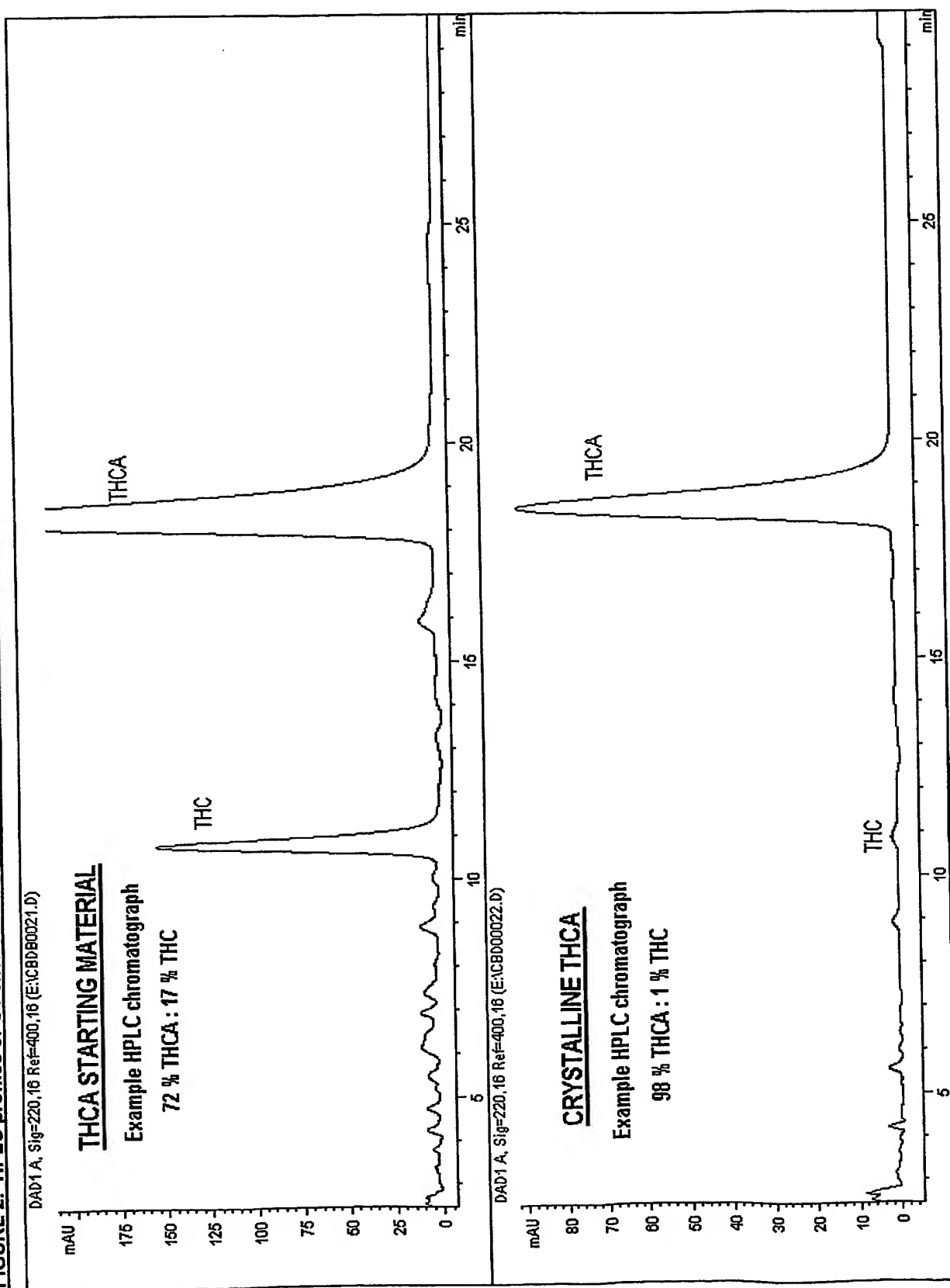
v) loading the substantially pure cannabinoid or cannabinoid acid or the product enriched in a given cannabinoid or cannabinoid acid onto a Chromabond Flash BT 12M silica cartridge column, eluting with

30 hexane:ethyl acetate (98:2) at a flow rate of approximately 5 ml/min.

**Figure 1:** TLC profile of G1 chemovar starting material and purified THCA

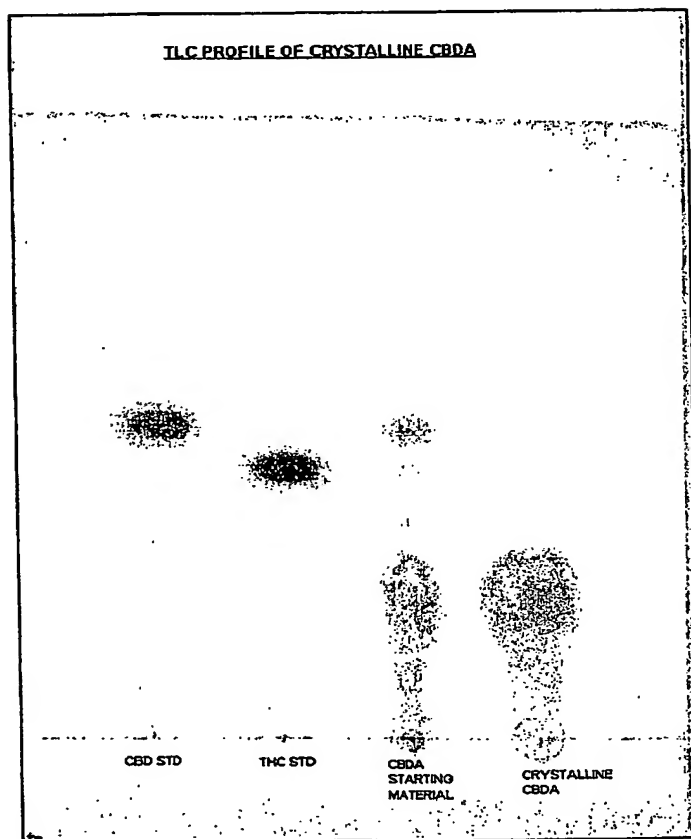


**FIGURE 2: HPLC profiles of G1 chemovar starting material and purified d9 THCA**

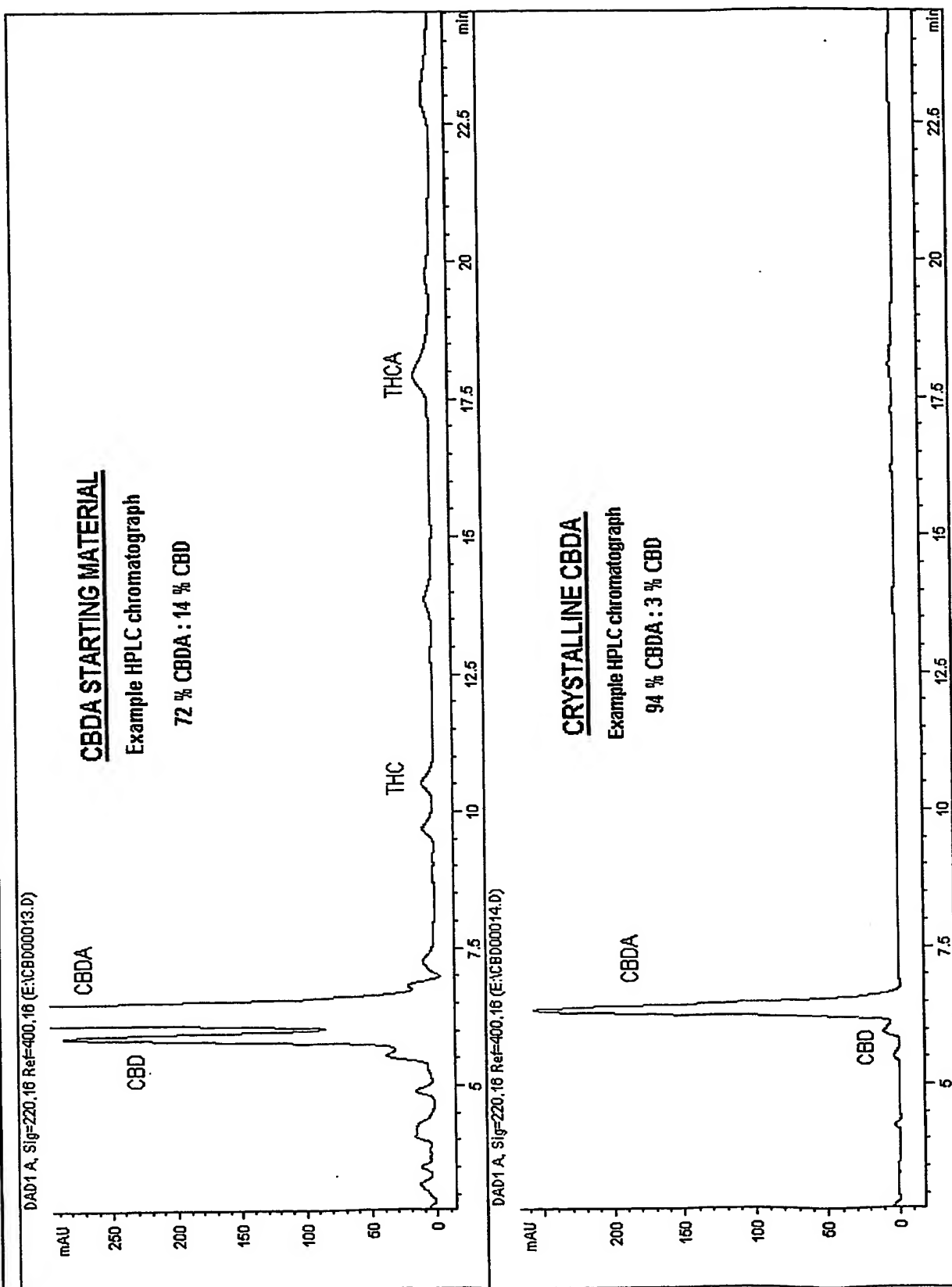




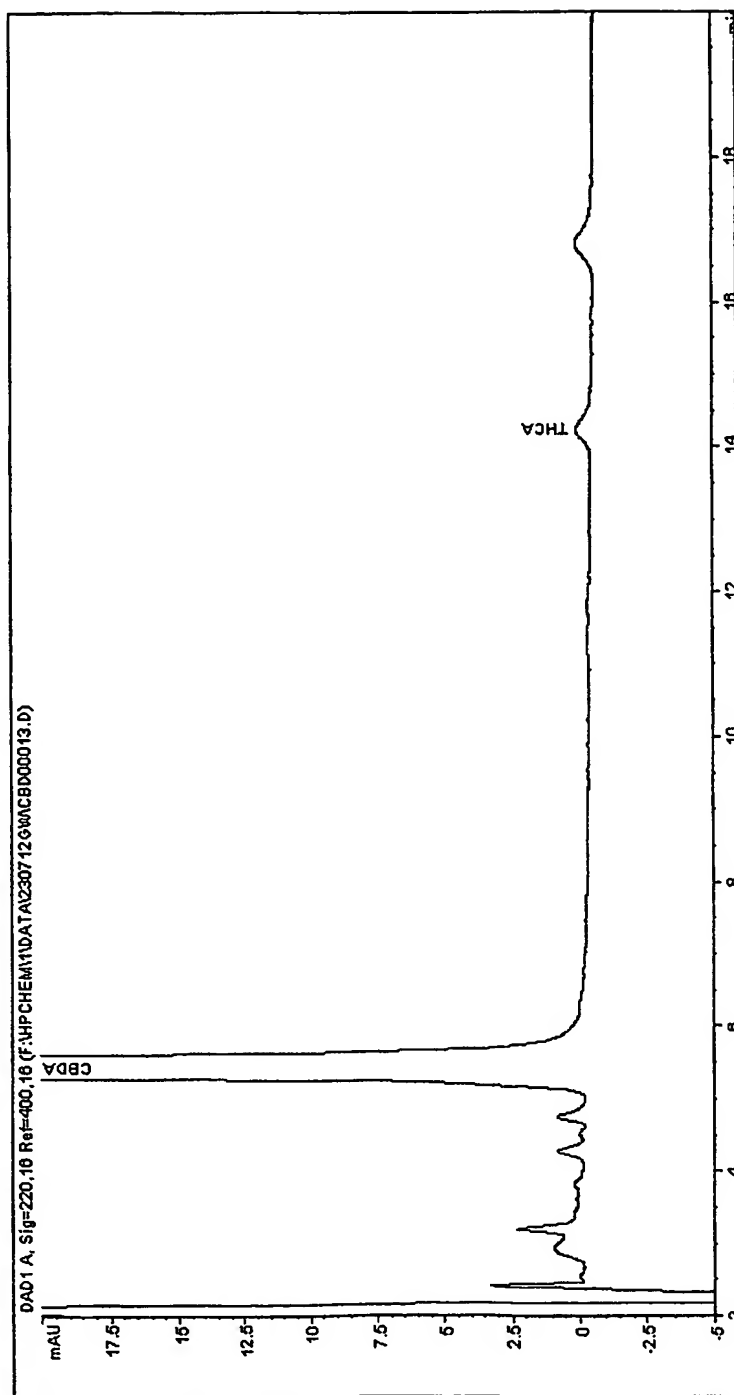
**Figure 3:** TLC profile of G5 chemovar starting material and purified CBDA



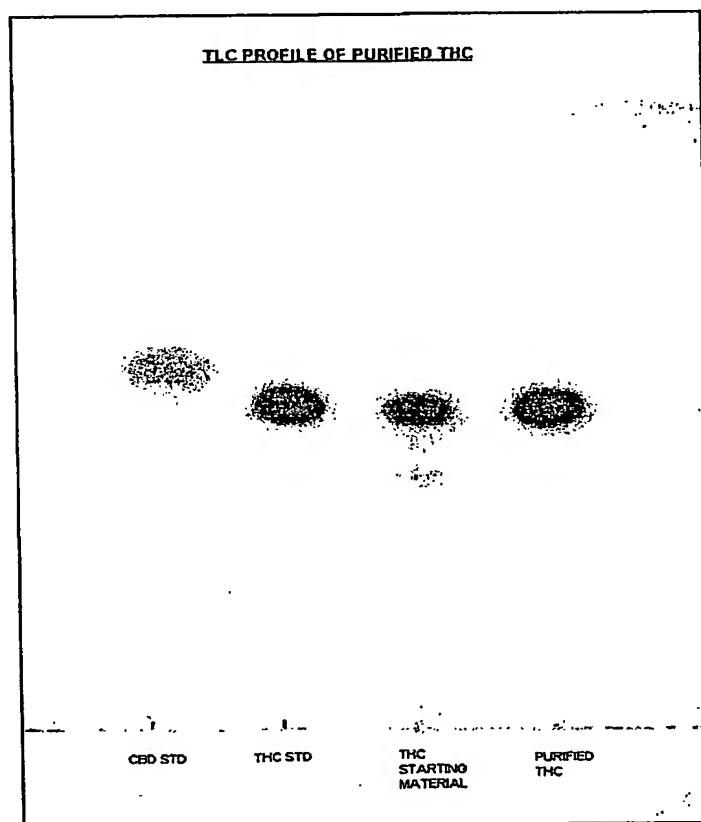
**FIGURE 4: HPLC profiles of G5 chemovar starting material and purified CBDA**

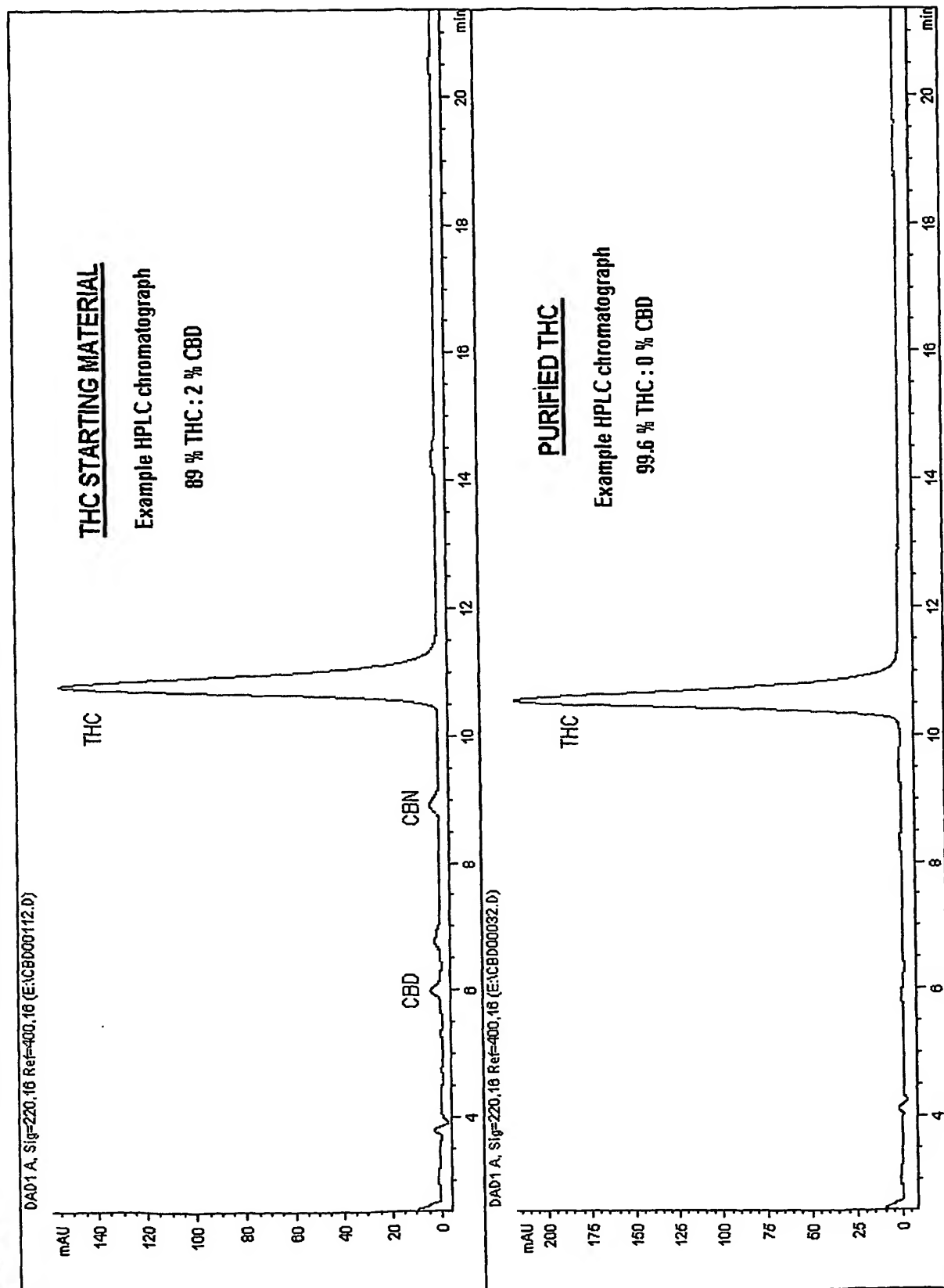


**Figure 5 - HPLC profile of colourless CBDA**

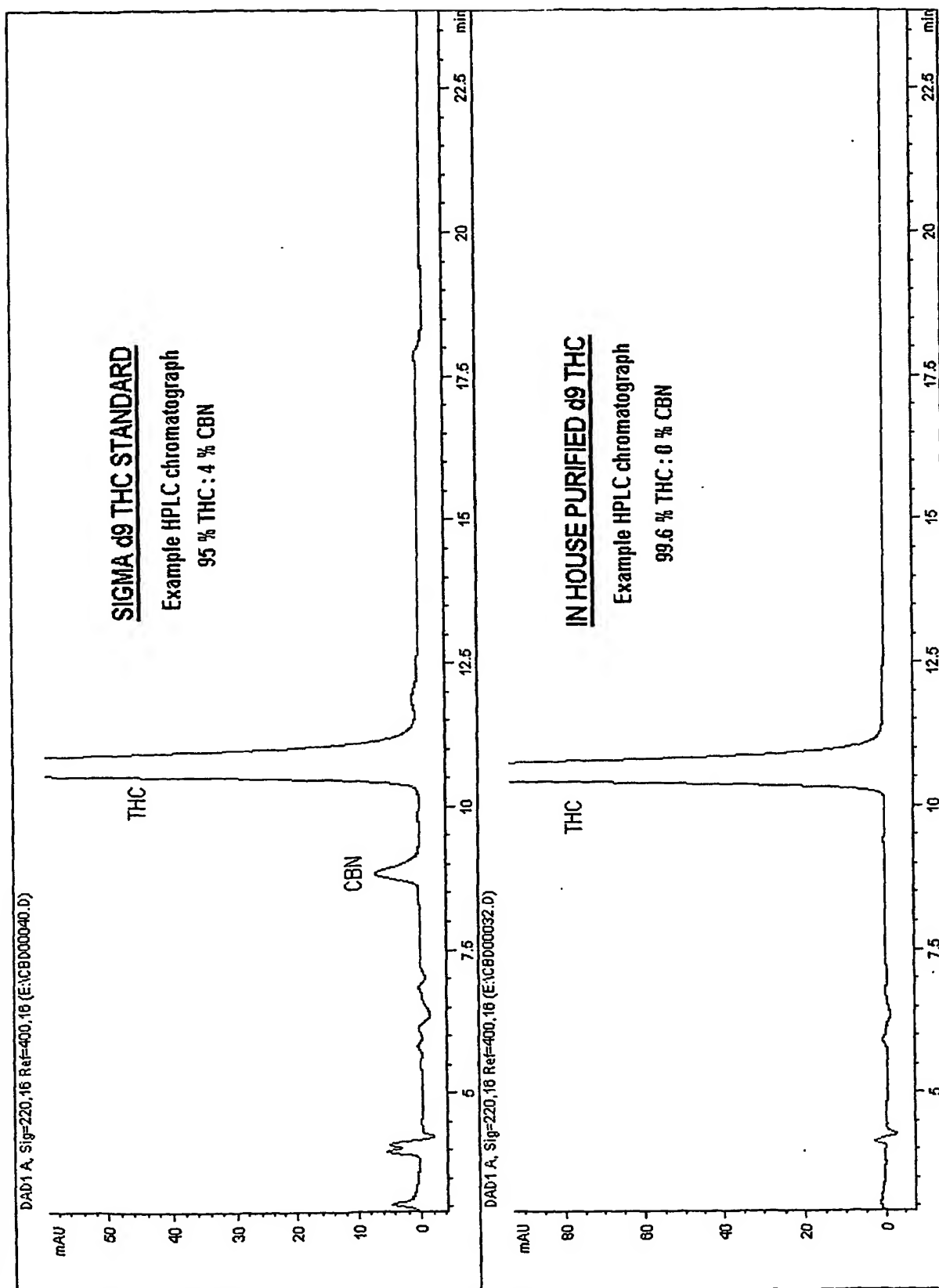


**Figure 6:** TLC profiles of BDS starting material and purified d9 THC

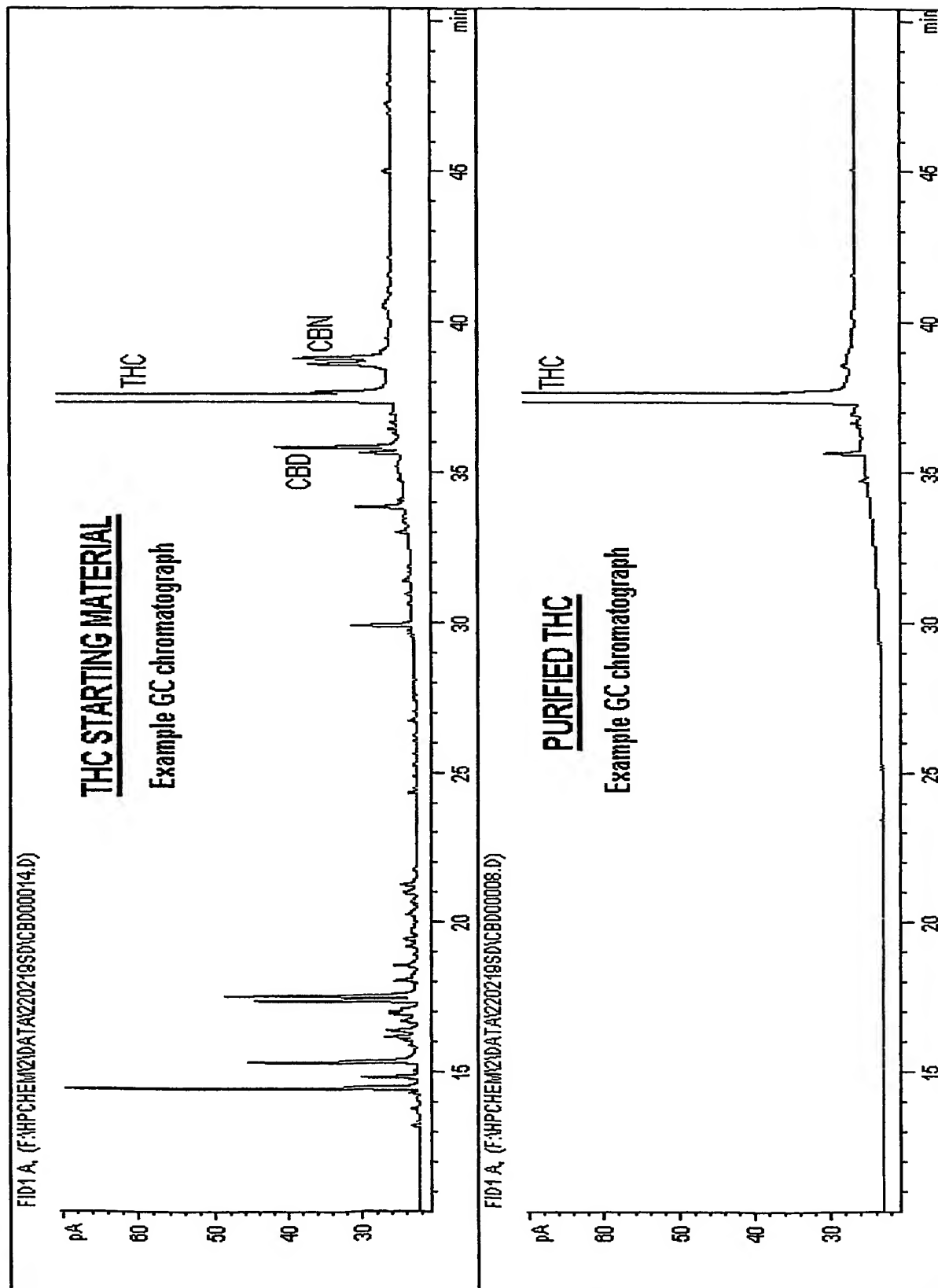


**FIGURE 7: HPLC profiles of BDS starting material and purified d9 THC**

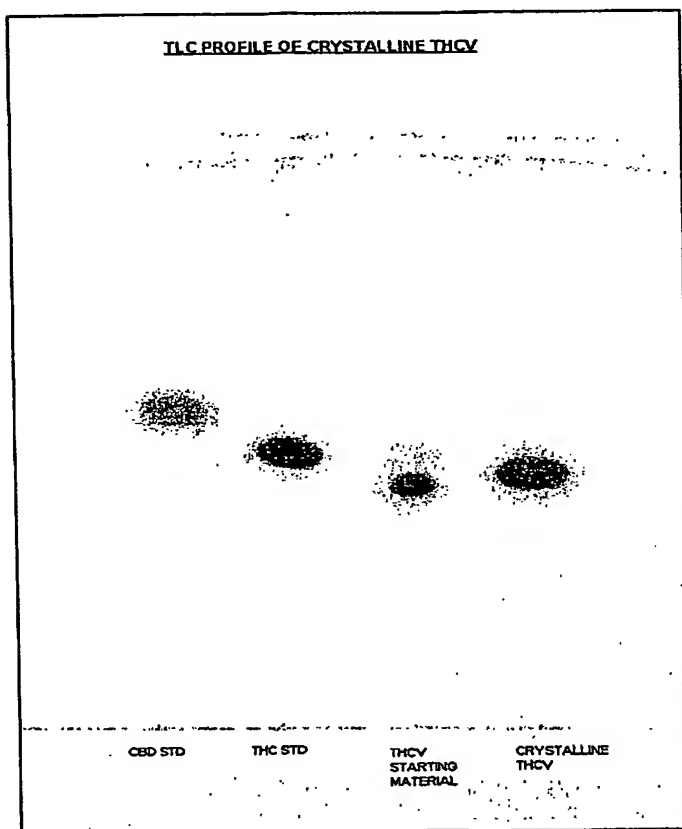
**FIGURE 8: Comparison of HPLC profiles of commercially available d9 THC standard (ex Sigma) and in house purified d9 THC**



**FIGURE 9: GC profiles of BDS starting material and purified d9 THC**

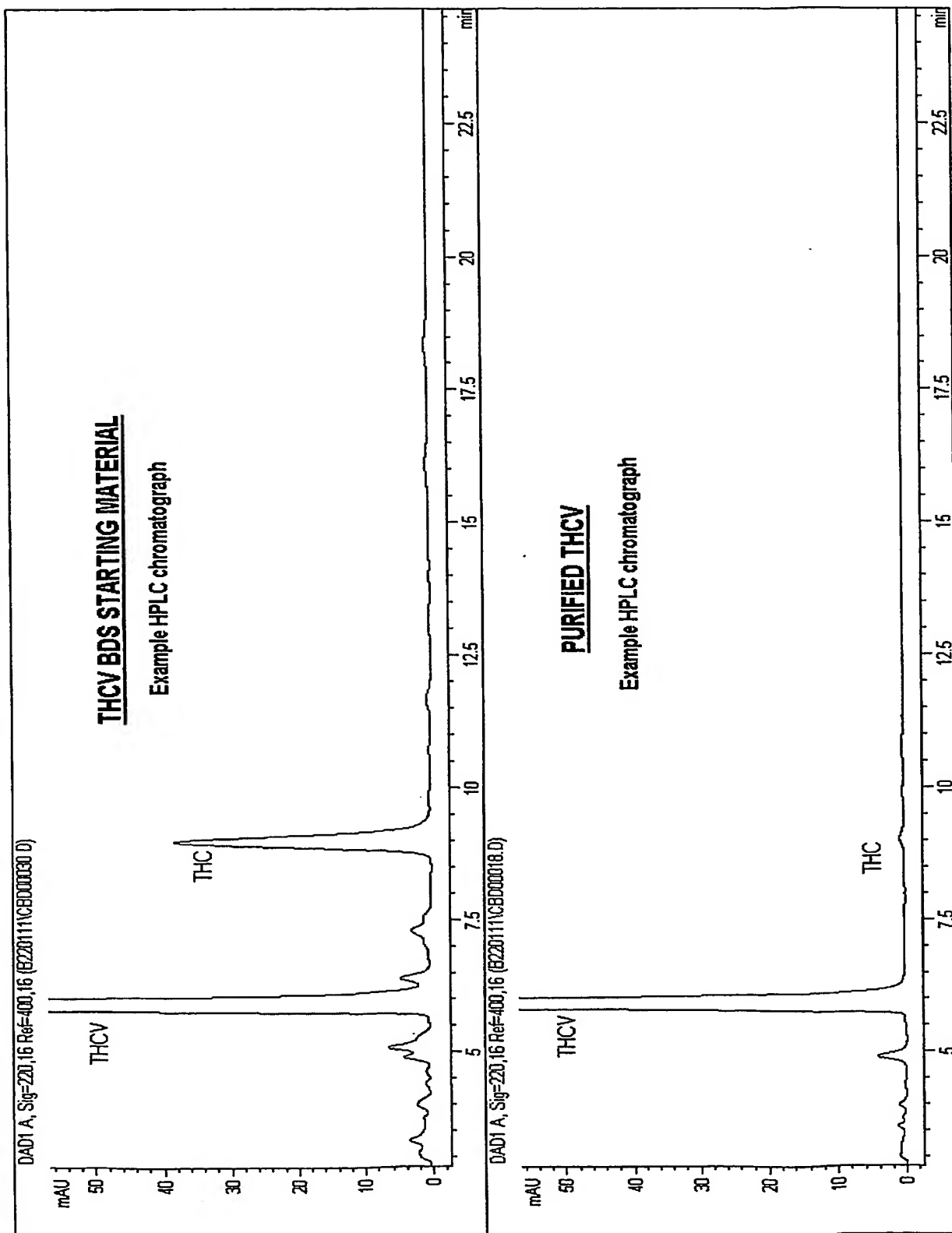


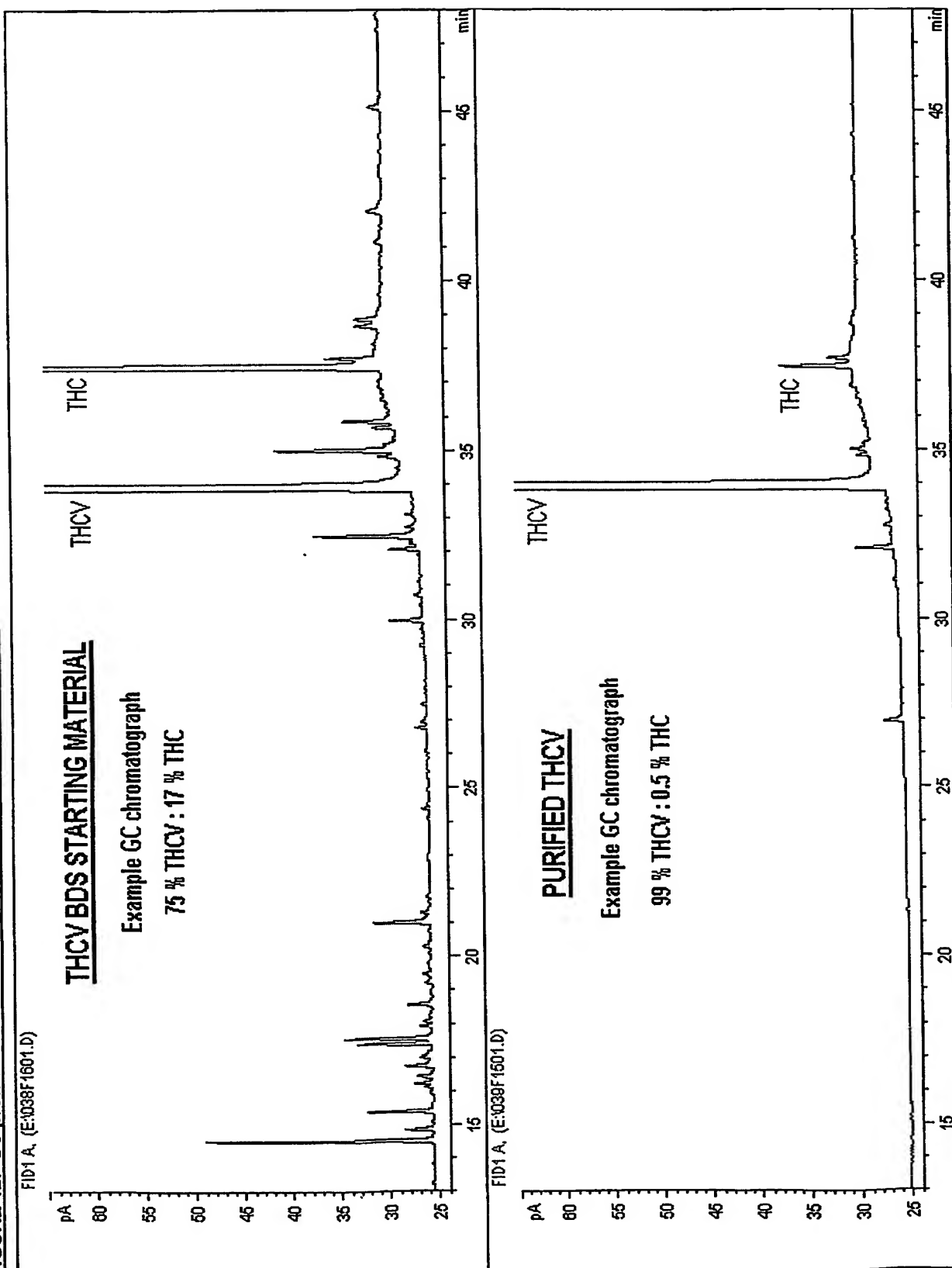
**Figure 10:** TLC profiles of BDS starting material and purified d9 THCV



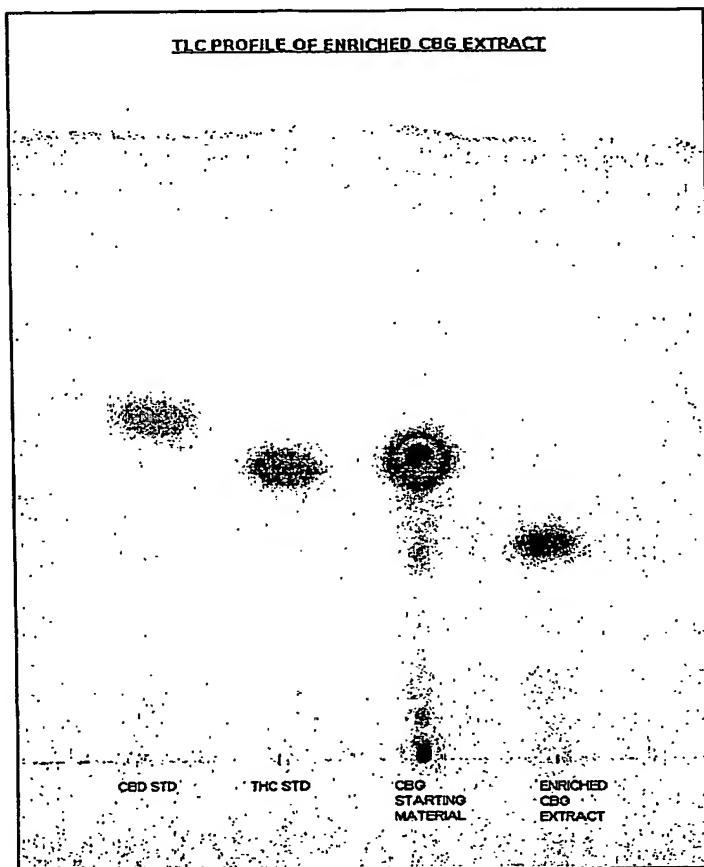


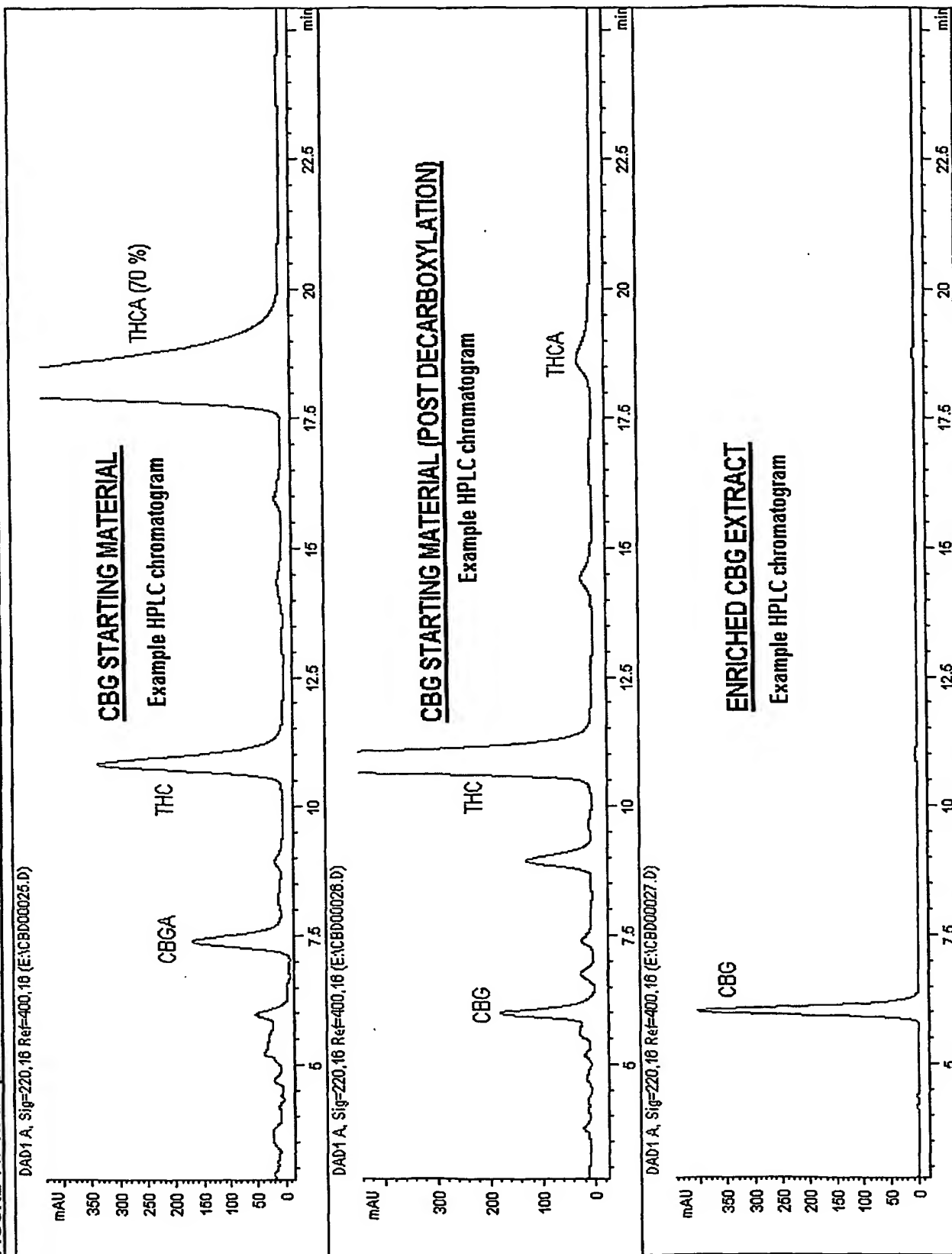
**FIGURE 11: HPLC profiles of BDS starting material and purified d9 THC**



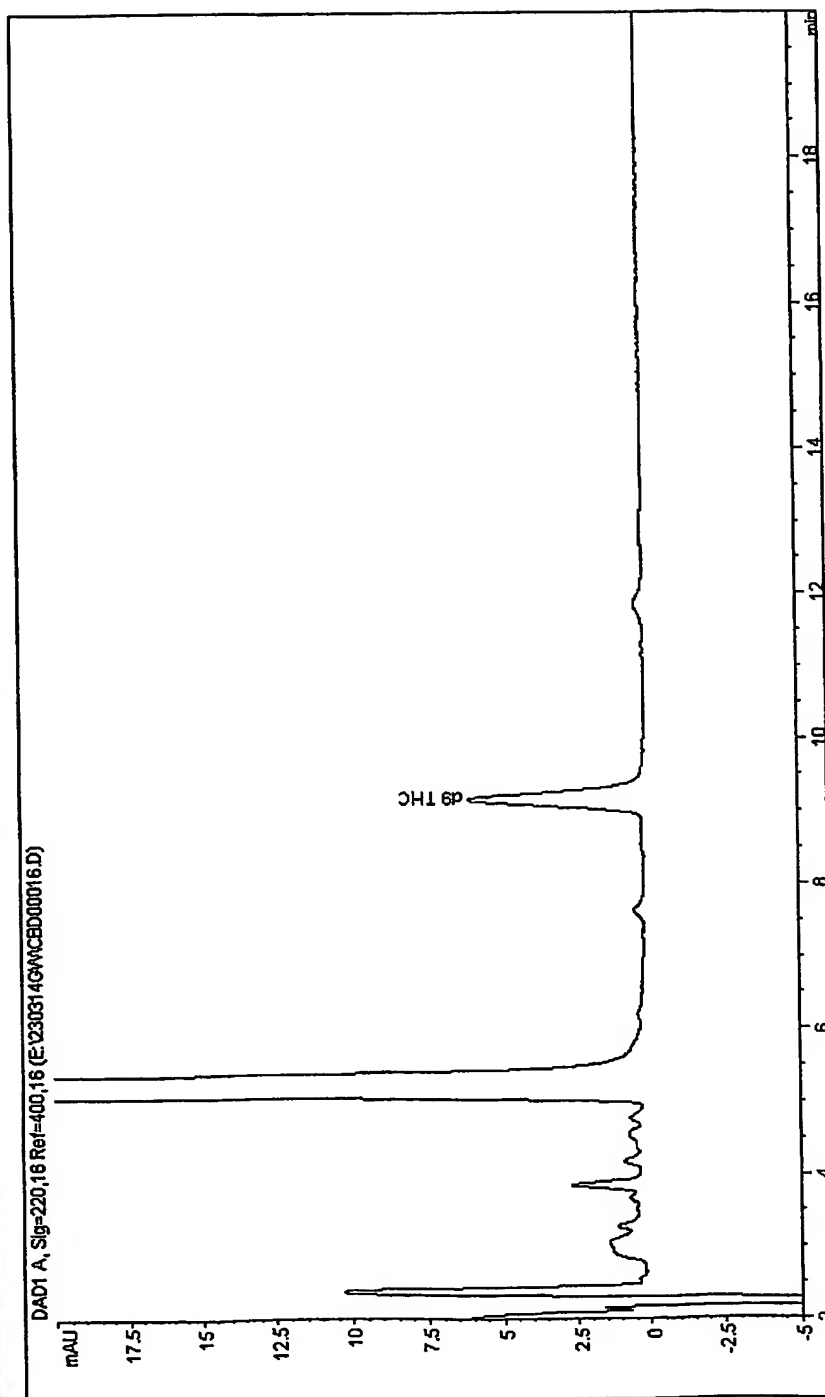
**FIGURE 12: GC profiles of BDS starting material and purified d9 THC**

**Figure 13:** TLC profiles of G41chemovar starting material (post decarboxylation) and enriched CBG extract.



**FIGURE 14: HPLC profiles of G41 chemovar starting material, pre and post decarboxylation, and enriched CBG extract**

**Figure 15 - HPLC profile of colourless solution CBG preparation**



**Figure 16 - HPLC profile of further flash chromatography purified CBG preparation compared to Improved purity CBG**

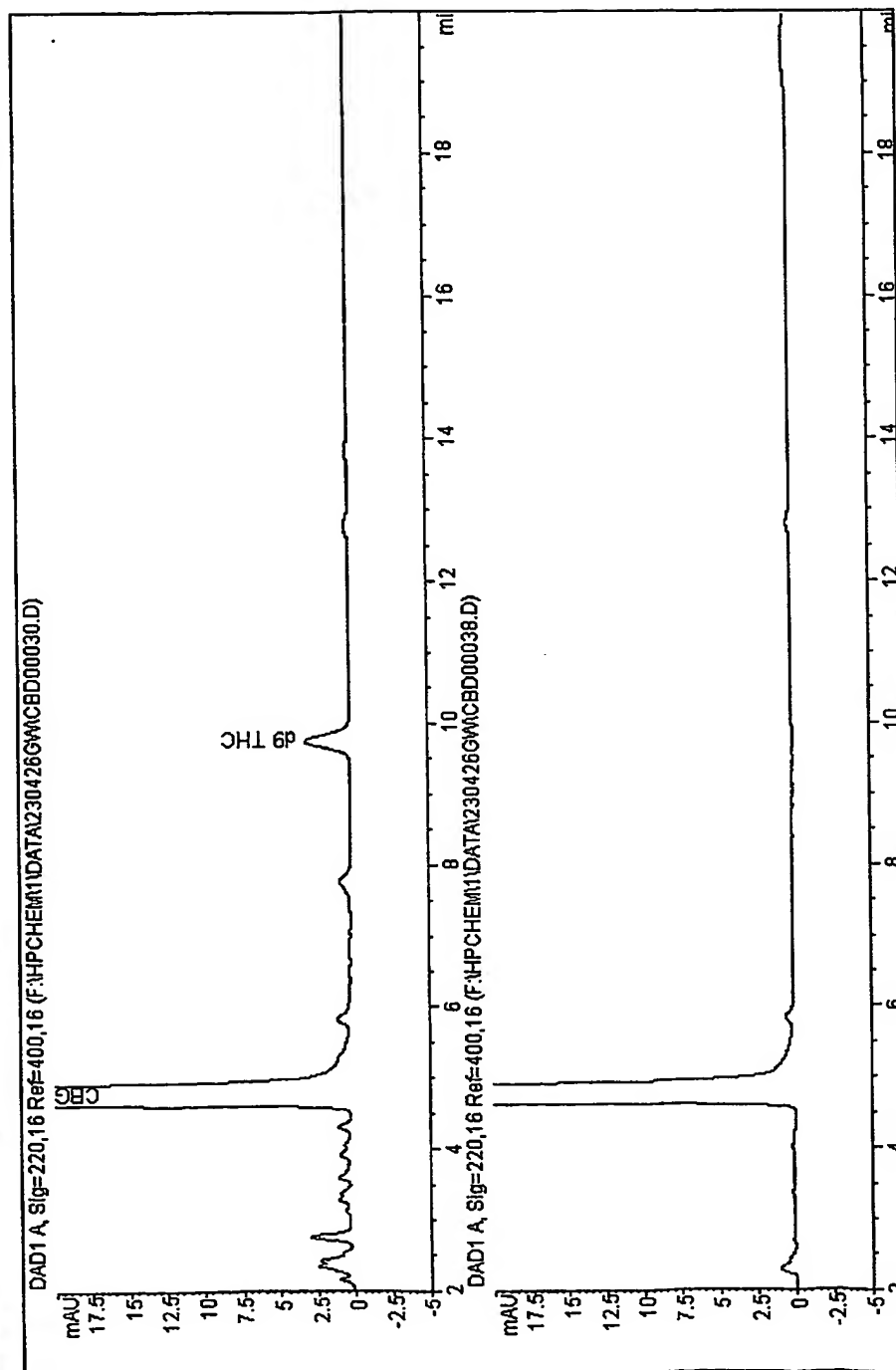
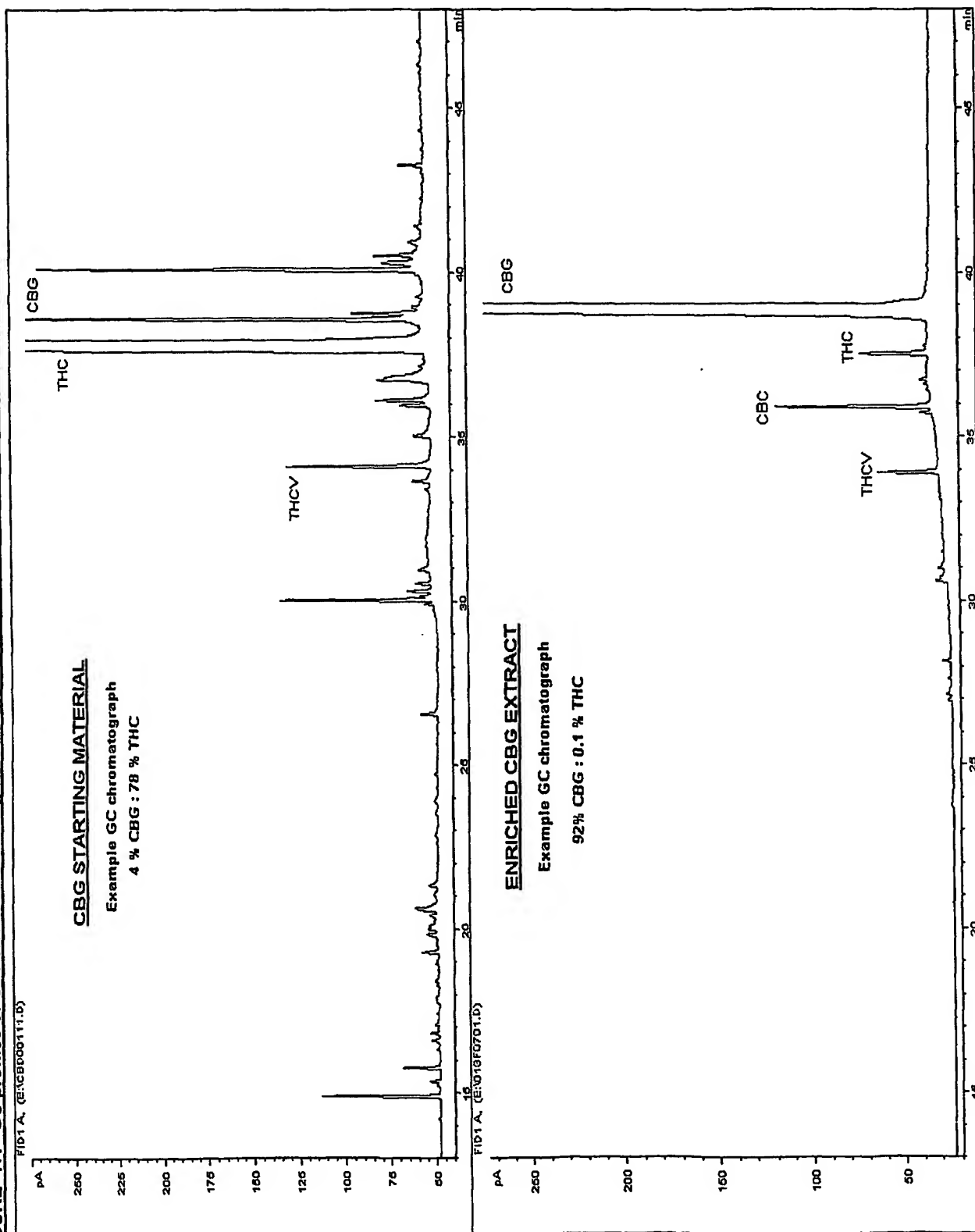
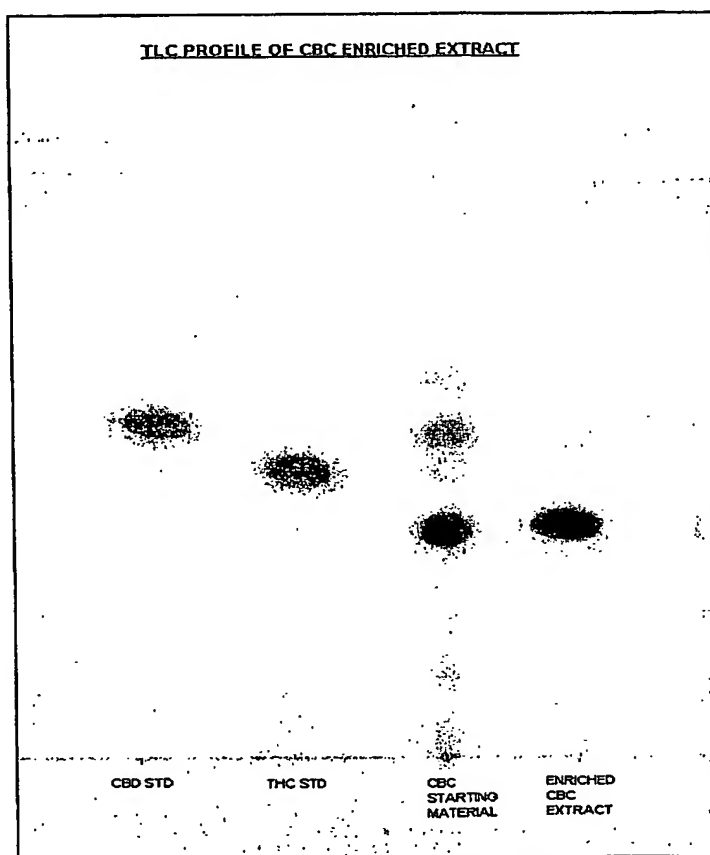


FIGURE 17: GC profiles of G41 chemovar starting material (post decarboxylation) and enriched CBG extract.



**Figure 18:** TLC profiles of G80 chemovar starting material  
(post decarboxylation) and enriched CBC extract.





**FIGURE 19: HPLC profiles of G80 chemovar starting material, pre and post decarboxylation, and enriched CBC extract.**

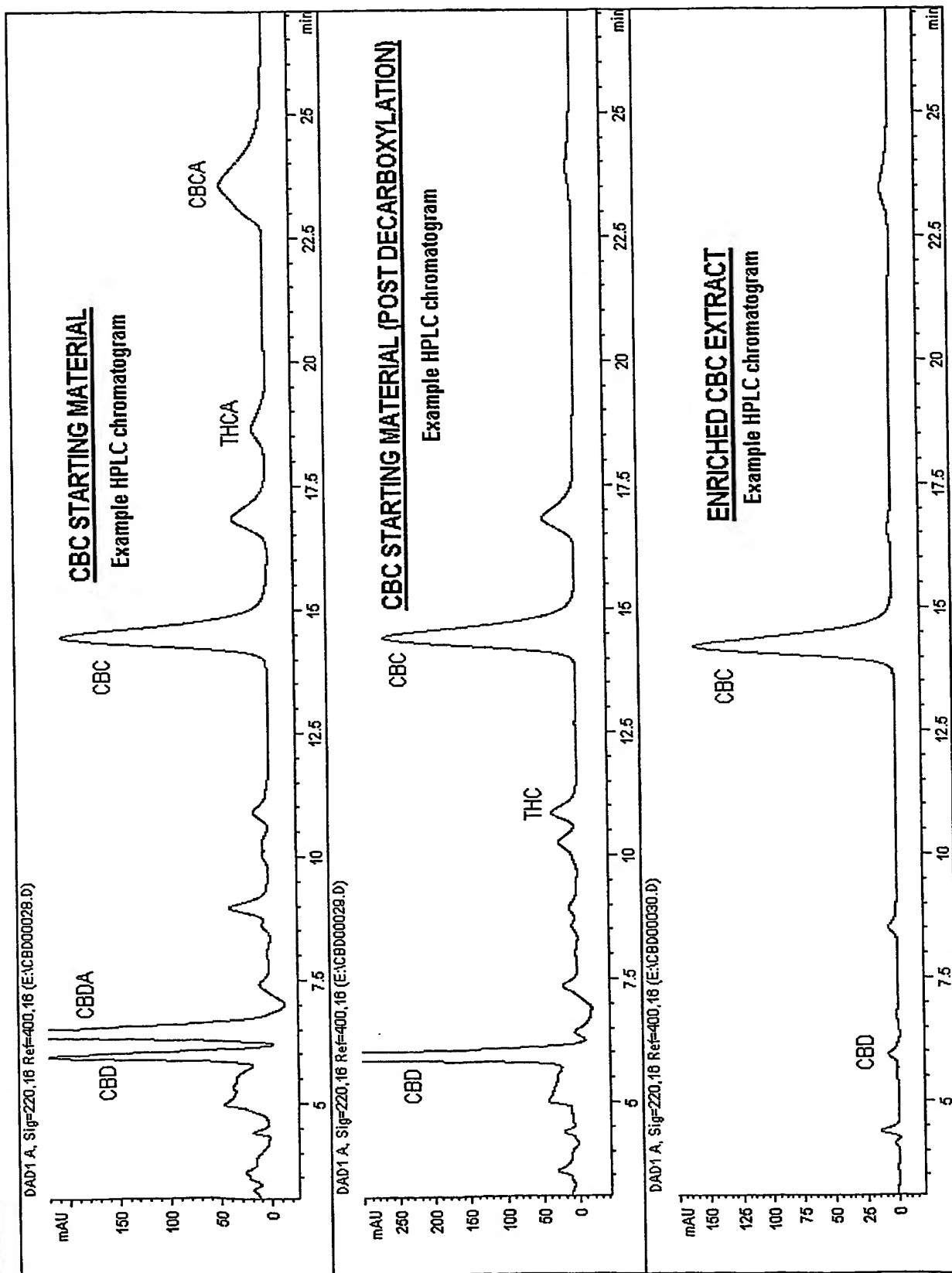
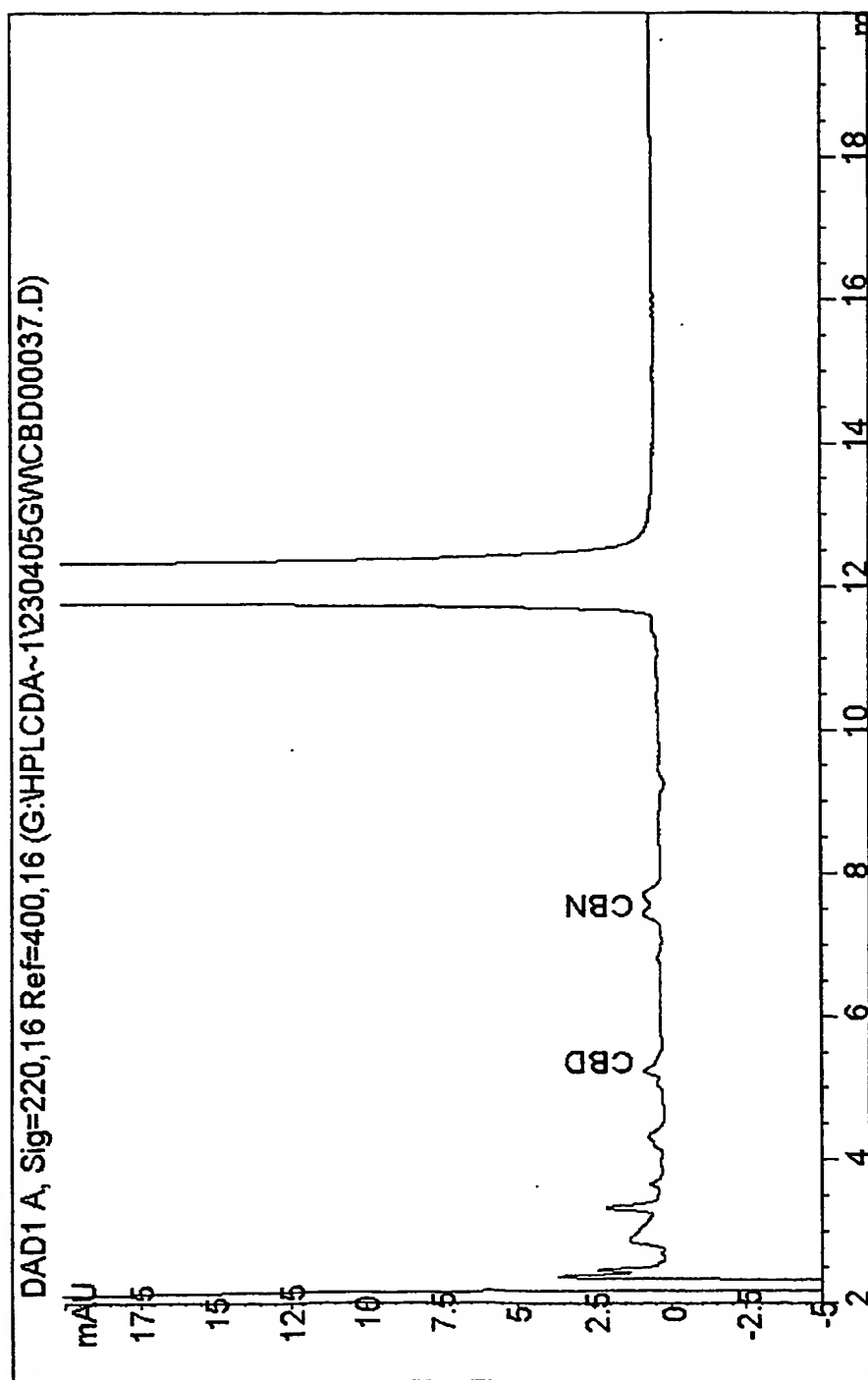
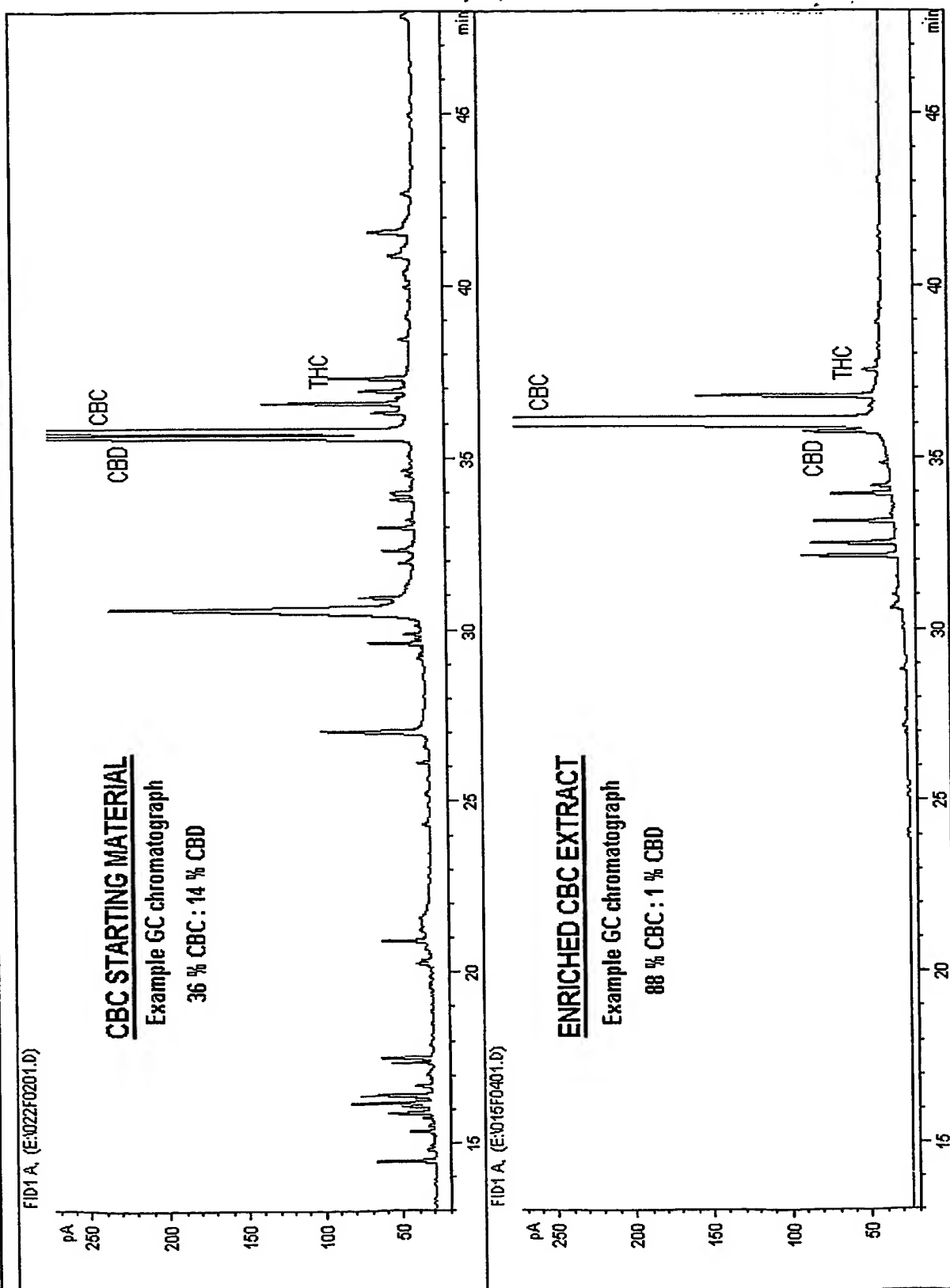


Figure 20 - HPLC profile of colourless solution CBC preparation



**FIGURE 21: GC profiles of G80 chemovar starting material (post decarboxylation) and enriched CBC extract.**



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